STUBBLE MULCH AND OTHER CULTURAL PRACTICES

for moisture conservation and wheat production

at the Wheatland Conservation Experiment Station Cherokee, Okla., 1942-1951

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STUBBLE MULCH AND OTHER CULTURAL PRACTICES FOR MOISTURE CONSERVATION AND WHEAT PRODUCTION AT THE WHEATLAND CONSERVATION EXPERIMENT STATION, CHEROKEE, OKLAHOMA, 1942-1951[1]

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INTRODUCTION

Stubble mulch and other cultural practices for moisture conservation and wheat production were studied on the Wheatland Conservation Experiment Station in Alfalfa County near Cherokee, Okla., from 1942 to 1951, inclusive. This station occupies 320 acres of land which is typical of a large amount of the wheat-producing area of Oklahoma and Kansas. It was established in July 1939, and experimental plots were ready for operation at the start of the 1941-42 crop season.

THE STATION SOIL

The station soil, described as Grant very fine sandy loam, is deep, permeable, and fertile, with rolling topography. This particular site was selected, because it represents a very large part of the wheatland of the region.

The surface soil consists of 6 to 12 inches of brown silt loam or very fine sandy loam, which is friable and easily cultivated. The soil grades into dark brown, heavy, very fine, sandy loam or silt loam at about 15 to 20 inches. It then passes into crumbly, dark brown to reddish brown, friable, sandy clay loam at depths of about 24 to 30 inches. This layer is very permeable. Below a depth of 4 feet, the material is sandy; in places a few fine quartz pebbles occur in the subsoil, and in others the soil is underlaid by beds of fine gravel.

When moist, the soil is dark; but, after drying, it is grayish brown on the immediate surface. It is developed over red beds consisting of calcareous materials, shales, and sandstones of fine texture. These beds have weathered deeply, producing a well developed soil, which is not calcareous above a depth of 3 feet but is about neutral in reaction.

METEOROLOGICAL RECORDS

Daily meteorological data were recorded at the station. Amounts and intensities of rainfall were measured by Ferguson recording rain gages at ten points located systematically. Each of these recording instruments was checked by standard gages at the respective locations. Temperature, humidity, evaporation, and wind movement were recorded by standard Weather Bureau equipment near the field office.

Precipitation

Average annual precipitation for the 10-year period was 27.01 inches (Table 8)[3], which is about average. There were two extremely wet seasons and also two abnormally dry seasons (Figure 1). The long-time Weather Bureau record at Cherokee shows that 64 percent of the time annual precipitation ranges between 20 and 30 inches; 19 percent, less than 20 inches; and 17 percent, more than 30 inches. Little effective rainfall

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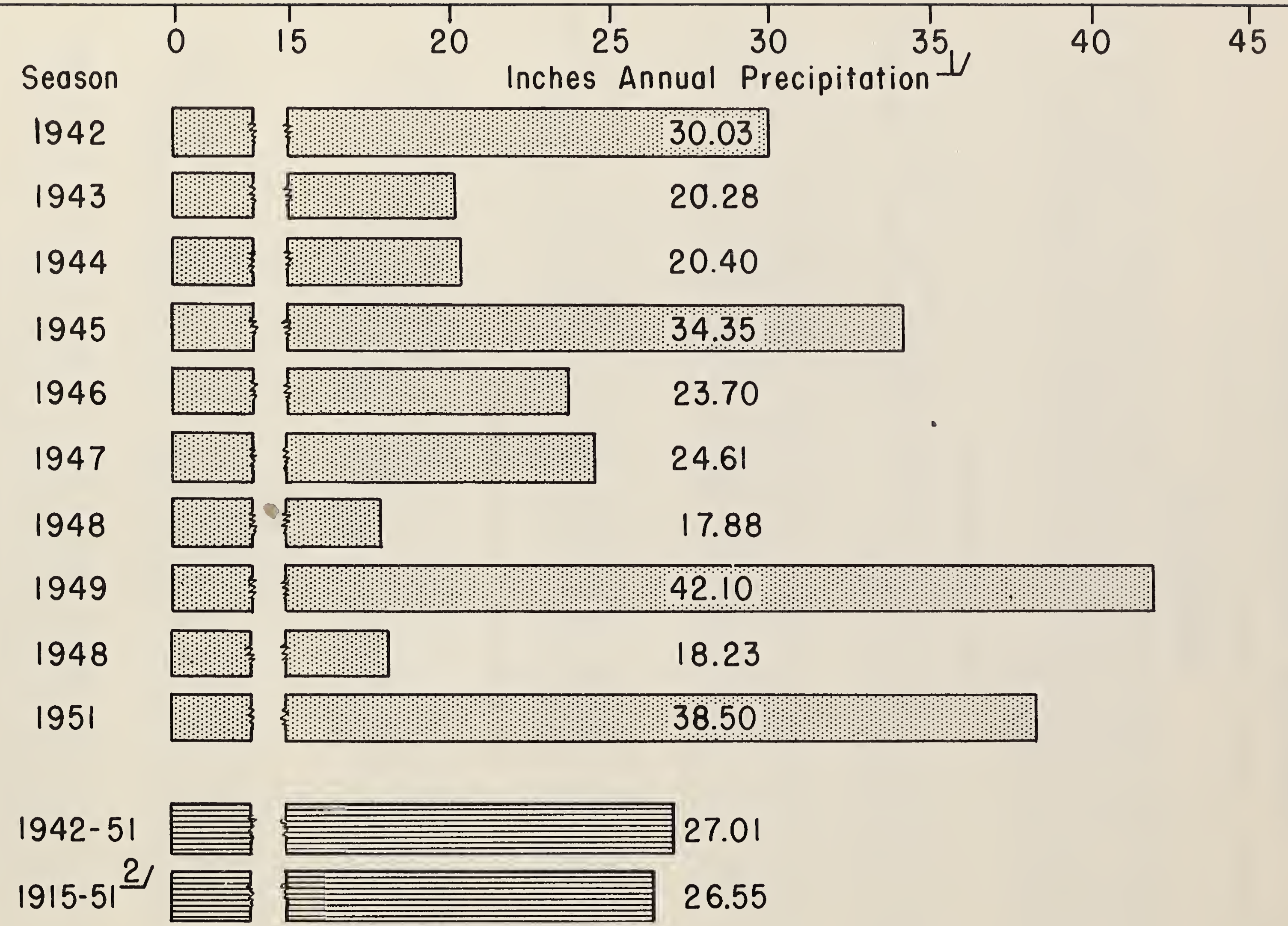
[1] These investigations were established under a cooperative research project of the Soil Conservation Service and the Oklahoma Agricultural Experiment Station. They are now conducted by the United States Department of Agriculture, Agricultural Research Service, Soil and Water Conservation Research Branch, and the Oklahoma Agricultural Experiment Station.

[2] Soil Conservationist and Agricultural Engineer (Soil and Water Conservation Research Branch) and Agronomist (Field Crops Research Branch), Agricultural Research Service, United States Department of Agriculture, Guthrie, Okla.

[3] In order to avoid an excess of tabular material throughout the text, Tables 8 through 21 have been placed in the appendix.



[1] For crop year from July 1 to June 30, 1942, through 1951.
[2] Based on Weather Bureau records in Cherokee since 1915.

FIGURE 1. --Annual Precipitation at Wheatland Station.

occurred during the late fall and winter. The highest average monthly amounts have been recorded in April, May, June, and August; and the lowest in November, December, January, and February (Figure 2 and Table 9). Long drought periods occurred frequently between the intense rains of summer. During fall and winter, rainfall generally comes in storms of long duration without intense bursts; but spring and summer are characterized by storms of short duration and high intensities (Table 1). The maximum rainfall intensities by crop seasons for the 10-year period, for 5-, 15-, 30-, 60-, and 120-minute intervals, were 7.20, 4.20, 3.36, 2.68, and 1.50 inches per hour, respectively (Table 2). The lowest maximum intensities during these time intervals were 3.00, 1.92, 1.46, 0.94, and 0.54 inches per hour.

Other Climatic Conditions

Other climatic records are recorded in Tables 8 and 9. The highest temperature was 116° F. and the lowest 18° below zero. The average maximum was 65° F. and the average minimum 43°. The summers are usually dry and hot. The highest relative humidity usually occurred in early morning and the lowest in early afternoon. The average maximum percentage of relative humidity was 86 and the minimum, 54. In general, there was considerable wind movement throughout the year (Figure 3), the highest occurring during March and April and the lowest in August.

The annual average amount of water lost by evaporation during the warm season from an open metal tank was 53.5 inches, which was about 2.25 times the amount of rainfall. The highest monthly evaporation occurred in July (Figure 4).

Table 1. Maximum monthly rainfall intensities for period, 1942-51, at Wheatland Station, Cherokee, Okla.

Month	Intensities in inches per hour during intervals of:				
	5 minutes	15 minutes	30 minutes	1 hour	2 hour
July	7.20	4.20	3.36	2.34	1.24
August	4.80	3.40	2.92	2.34	1.21
September	3.84	2.40	1.92	1.60	1.14
October	4.56	3.84	2.64	1.65	1.18
November	.96	.64	.56	.36	.20
December	1.44	.72	.62	.45	.38
January	2.40	.88	.44	.28	.17
February	3.60	2.56	1.68	1.10	.80
March	6.00	3.12	1.58	.92	.51
April	4.80	3.04	2.16	1.60	.86
May	7.20	3.20	2.00	1.38	.66
June	6.24	4.00	3.18	2.68	1.50

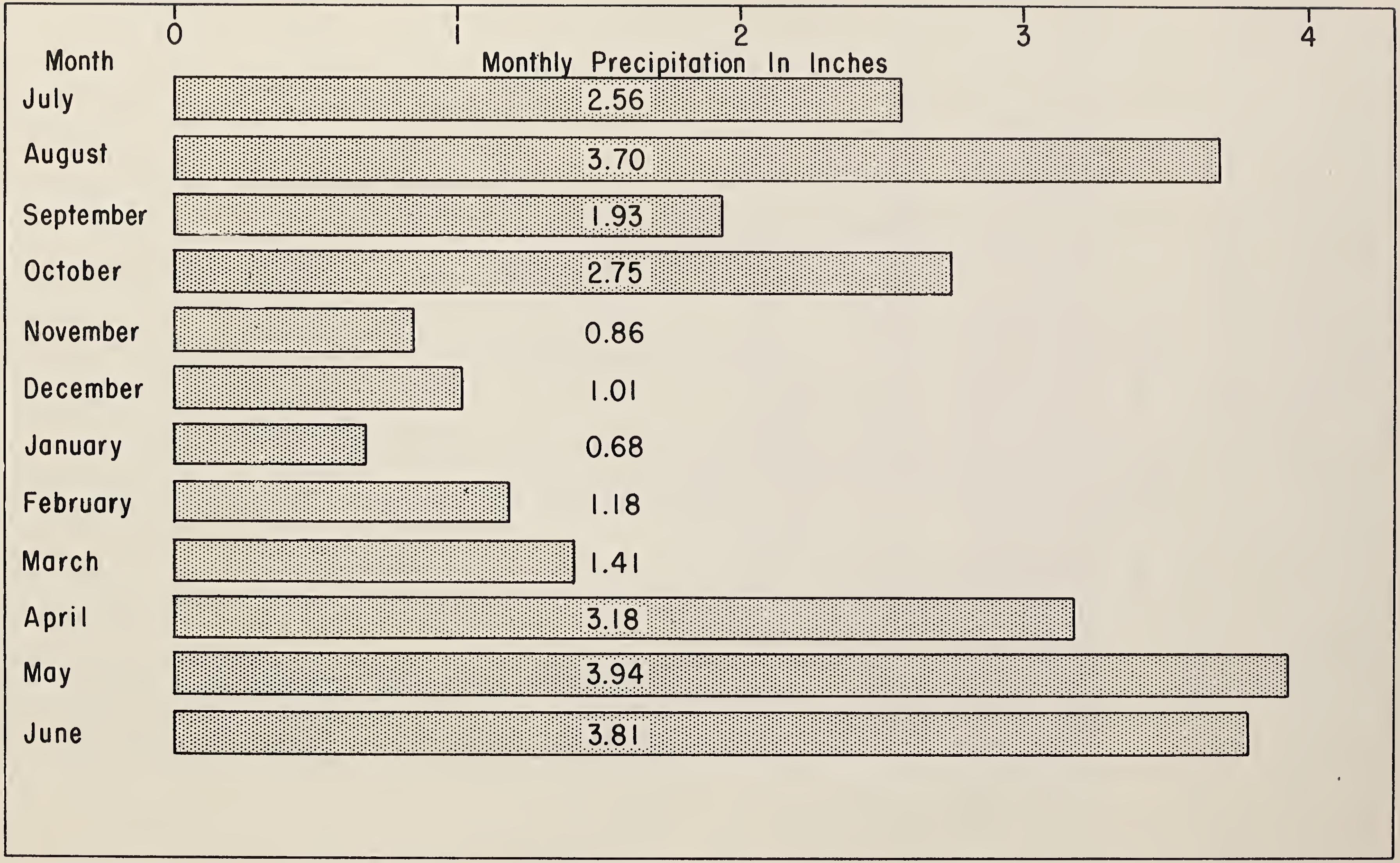


FIGURE 2. --Monthly Precipitation at Wheatland Station.

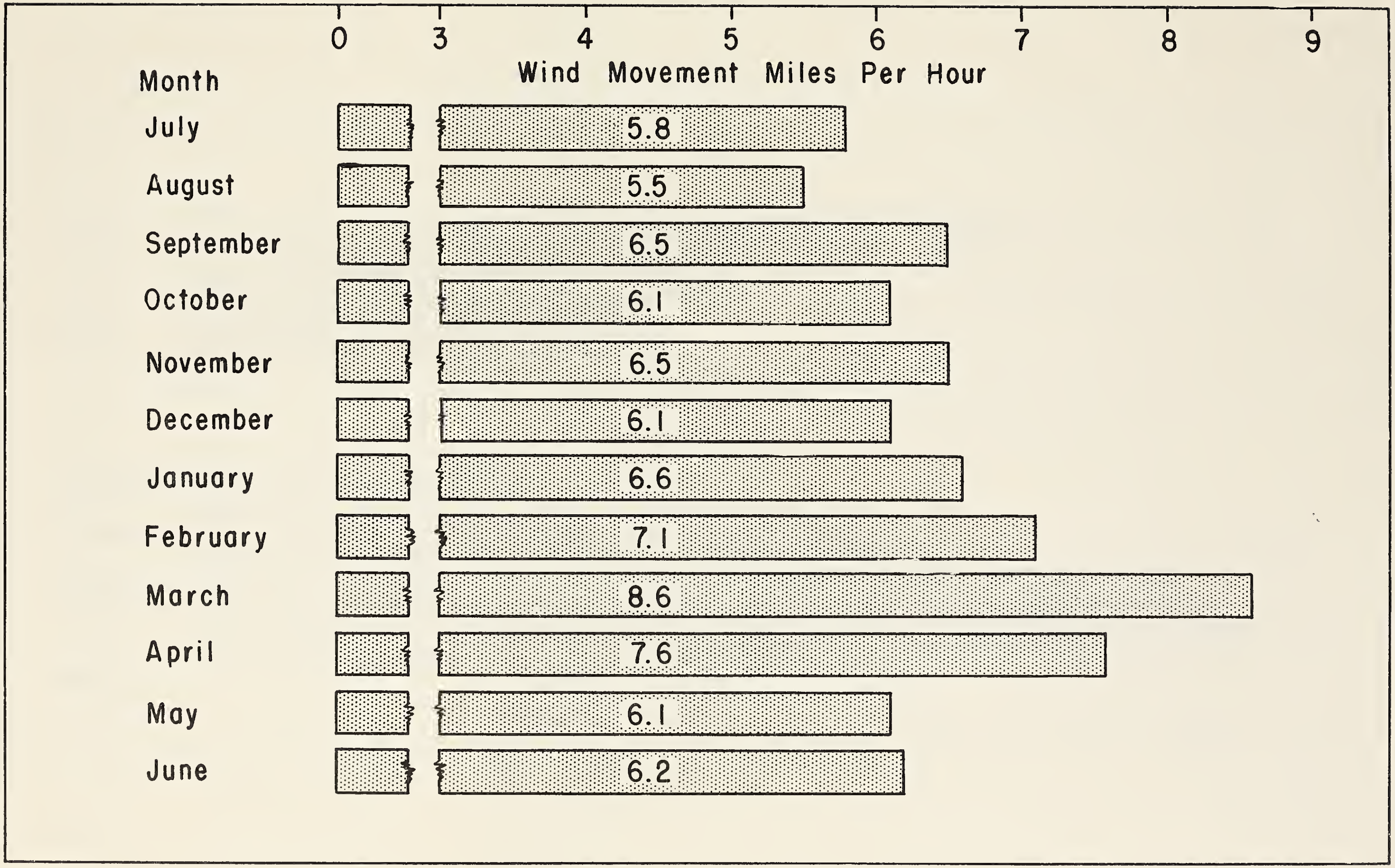


FIGURE 3. --Wind Movement at Wheatland Station.

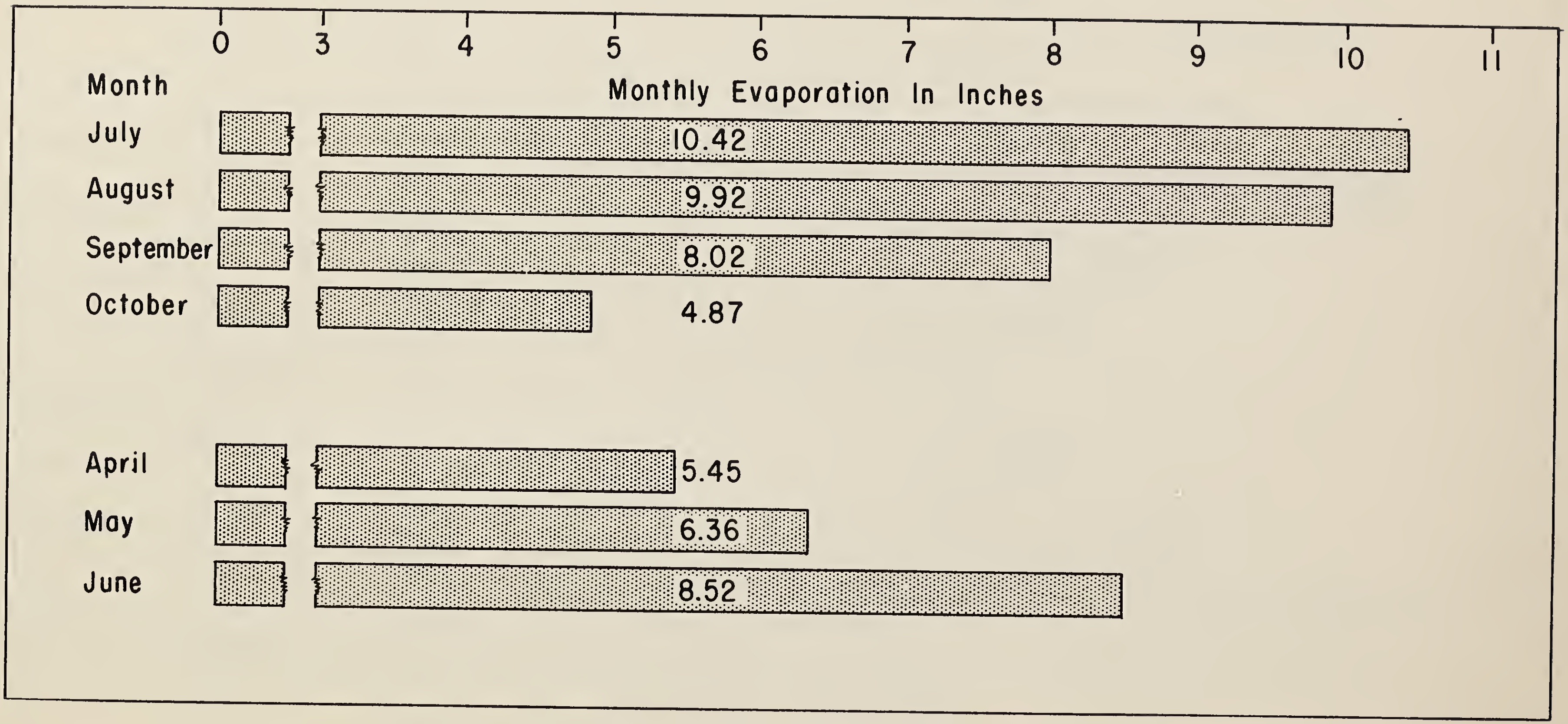


FIGURE 4. --Evaporation during Warm Season at Wheatland Station.

Table 2. Maximum annual rainfall intensities for period, 1942-51, at Wheatland Station, Cherokee, Okla.

Year	Intensities in inches per hour during intervals of:				
	5 minutes	15 minutes	30 minutes	1 hour	2 hour
1942	5.28	3.12	2.52	1.65	1.17
1943	3.84	1.92	1.60	1.42	1.18
1944	4.80	2.52	2.00	1.60	.86
1945	6.24	3.40	2.44	2.34	1.21
1946	5.76	3.44	2.72	1.60	1.14
1947	4.08	2.96	1.72	.94	.54
1948	3.00	2.56	1.68	1.10	.80
1949	7.20	3.84	2.92	2.02	1.30
1950	3.60	2.40	1.46	1.06	.60
1951	7.20	4.20	3.36	2.68	1.50
1942-51	7.20	4.20	3.36	2.68	1.50

GENERAL INVESTIGATIONAL PROCEDURE

The over-all objective of these investigations was to devise means of reducing runoff water and conserving moisture for plant growth on wheat land. Different methods of seedbed preparation in combination with contour cultivation and terraces for moisture conservation and wheat production were compared. Seedbeds were prepared by both continuous or annually recurring tillage (Table 10) and 3-year sequences of rotation tillage (Table 11). Various machines were used in these tests. The cropping system was continuous winter wheat which predominates in the region.

Methods of Continuous Tillage

Continuous tillage methods were studied on 48 plots, 32 of which were labeled "A" plots and the remaining 16, "B" plots. They were located on land in accordance with its slope and configuration. The "A" plots were located on slopes of 1.25 to 3.00 percent and the "B" plots, on slopes of from 3.00 to 5.00 percent. Each plot varied in size and land slope (Figure 5). The length of the "A" plots with the slope was the interval of six contours spaced at one foot. The width of plot was designed so that the average length of the contour was equal to, or slightly greater than, the length of slope within the plot. The length of the "B" plots was the interval of eight contours spaced at one foot, and the width was determined in the same manner as that of "A" plots. In general, "A" plots occupy Class II land and "B" plots, Class III land.

This experiment was designed to determine the effectiveness of different methods of continuous or annually recurring tillage on terraced and unterraced land for water conservation and crop production. The terraces were built level with a vertical interval of 3 feet on the "A" plots and 4 feet on the "B" plots. The main tillage practices were:

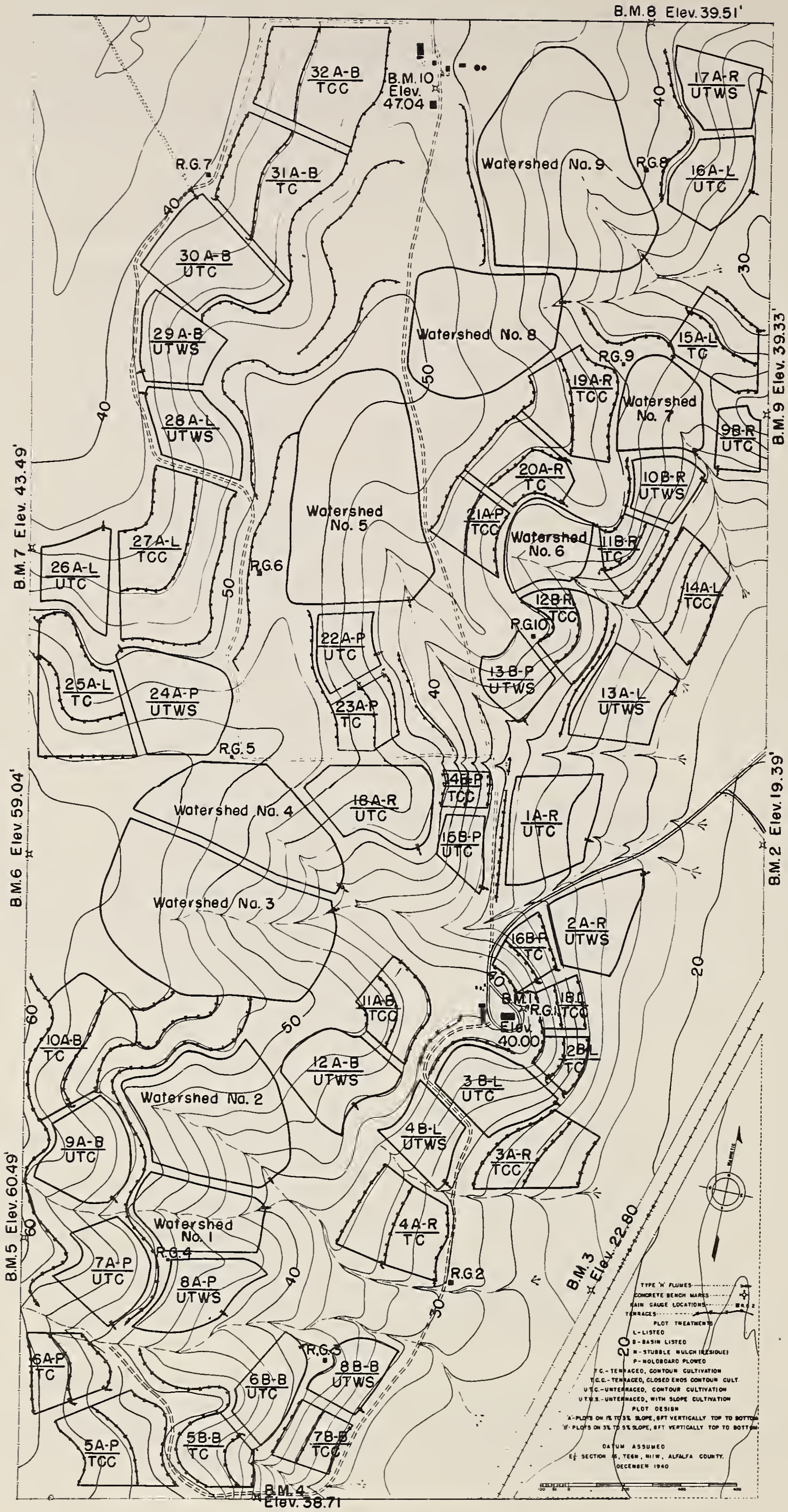


FIGURE 5. --Wheatland Conservation Experiment Station Cherokee, Okla., 1940.

1. Plowed with moldboard plow.

2. Listed with standard 42-inch lister.

3. Basin listed with standard 42-inch lister equipped with damming attachments.

4. Stubble mulched; crop residues left on surface.

These methods of tillage were each applied on plots treated as follows:

1. Terraced, level, one end closed and the other open, all cultivation on contour.

2. Terraced, level, closed ends, all cultivation on contour.

3. Unterraced, all cultivation on contour.

4. Unterraced, all cultivation with slope.

These eight practices were each assigned in triplicate to individual plots by random selection, which made a total of twelve plots for each treatment. This design was for mathematical manipulation of data accumulated. Statistical analysis was made of data on runoff, moisture, and crop yields. This analysis is available in another report (1). Conclusions made from results of continuous tillage experiments are based on statistical interpretation.

Plots were separated by alleyways, which allowed ample space for turning farm machinery during tillage operations, and were delineated by small earth dikes. The different tillage practices were applied on plots immediately after harvest. Stubble mulch culture is a tillage method designed to leave crop residues of straw on or near the surface (Figure 6). It was performed with plow-lay (Figure 7) and Raydex sweeps (Figure 8). Plow-lay sweeps were used for the first tillage and later cultivations were made with Raydex sweeps. Weed growth during the summer was controlled on plowed plots with a field cultivator or springtooth harrow. On listed and basin listed plots, the second cultivation consisted of busting ridges with the same equipment used for the first tillage. Prior to seeding time, lister ridges on both areas were plowed down with a field cultivator. Wheat was seeded with a semi-deep furrow, disk-type drill with 10-inch spacings (Figure 9).

Methods of Rotation Tillage

Rotation tillage methods of seedbed preparation were designed to determine the effectiveness of 3-year sequences of one-way plowing, basin listing, and stubble mulch tillage. The experiment occupied nine small natural watersheds, which were divided according to size into groups of three (Figure 5). The first group contained approximately 2 acres each; the second, 4.5 acres; and the third, 8 acres. These areas were seeded to wheat continuously and cultivated and seeded on the contour. In general, they occupy Class II and III land.

Tillage methods were rotated on each watershed annually, with all treatments appearing each year in each of the three groups. These tillage practices were made immediately after harvest and weed growth was controlled during the summer as described previously for continuous tillage experiments.

INVESTIGATIONS AND RESULTS

Stubble Mulch Machinery

During the course of this experiment, suitable equipment for performing stubble mulch tillage was not available commercially. Developments reported here were of a pioneering nature. Several adapted commercial sweeps became available about the time this experiment ended.

FIGURE 6. --Stubble mulch of wheat straw on Wheatland Station.

FIGURE 7. --Plow lay sweeps.

These sweeps were constructed of a right and left 16-inch plow lay.

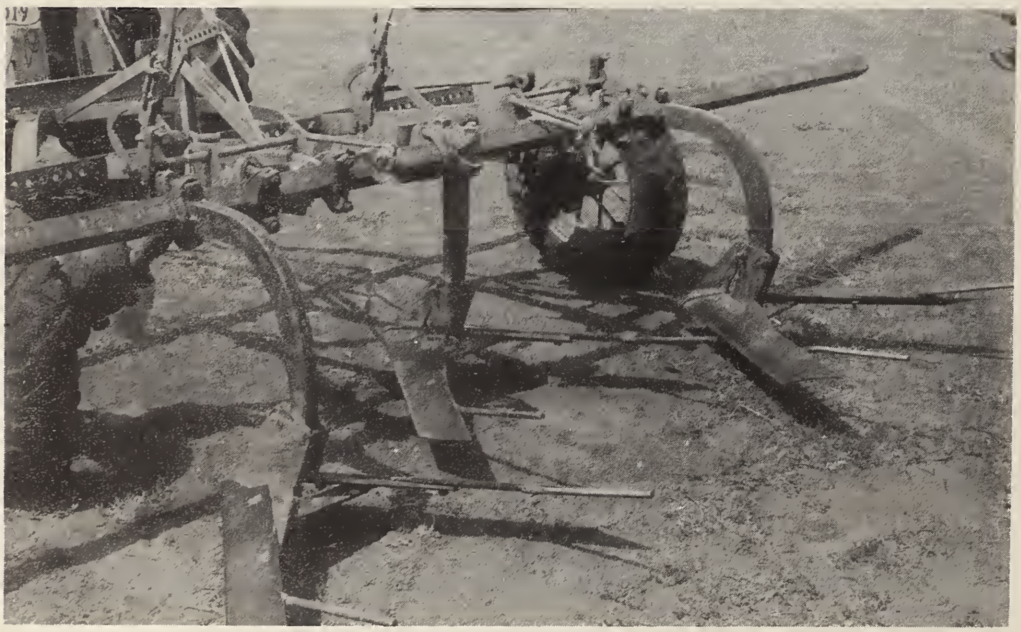


FIGURE 8. --Raydex sweeps.

Wings for these sweeps were made of Raydex plow lay stock and attached to the frog with plow bolts. They were constructed with the concave and also with the convex sides up, but no apparent advantage was noticed by either arrangement.

FIGURE 9.--Seeding wheat on stubble-mulch tilled land.

Wheat was seeded with a disk-type drill and straw did not interfere.

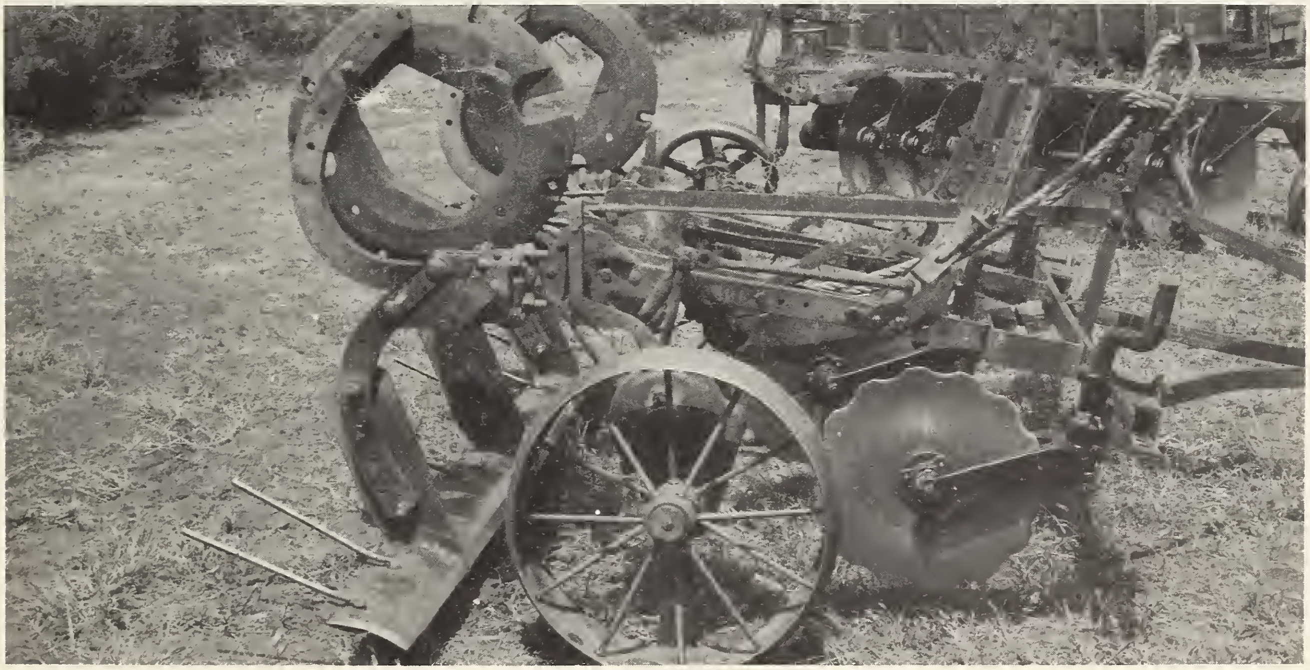


FIGURE 10.--Blade tiller.

The blade tiller was mounted on lister shanks but additional weight was necessary for maintaining uniform penetration of soil. Coulters helped eliminate accumulation of trash on shanks.

TYPES OF MACHINES TESTED

Various machines were tried on small areas not occupied by the continuous or rotation tillage studies. Those given considerable tests were sweeps, blade tillers, and disks of different kinds. Certain tools (Figures 8 and 10) were equipped with bars welded to the back side of blades to give a raking action to the underside of the furrow slice. The objective was to create more surface disturbance of soil without covering trashy material. These bars seemed to be of little value.

Standard pressed sweeps

Sweeps from 8 to 14 inches in width functioned satisfactorily on short stubble, but clogged when bunches of straw, wild pea vines, or large weeds were encountered. Sweeps, 20 to 24 inches wide, performed better but tended to bend and the shanks were still too close for good clearance.

Pence sweeps

These sweeps were 42 inches wide and made of flat blade material with an angle of 90°. The blades were welded to a forging bolted to the side of a lister shank or similar implement. In operation, they raised the soil only about an inch. This sweep operated without much clogging but its performance was improved by use of coulters. Difficulty was encountered with breaking of blades near the shank and it did not agitate soil sufficiently.

Plow-lay sweeps

Major problems encountered with sweeps were bending, breaking, clogging, and insufficient lift of soil to give good agitation. In an attempt to overcome these difficulties, a sweep was made from right-hand and left-hand plow lays (Figure 6). These sweeps operated well through trashy material when used with coulters, but some ridging occurred. They raised the soil approximately 2.5 inches. These large sweeps were difficult to sharpen. Consequently, they were redesigned, using lister bottoms for points and replaceable plow lays for wings. The lister bottoms and plow lays were bolted to a frog designed to fit lister shanks.

Raydex sweeps

In a further attempt to improve the design of sweeps, services of the USDA Tillage Machinery Laboratory at Auburn, Ala., were requested. Blades were cut from Raydex plow lay stock and fitted to the frog of a commercially made, assembled sweep (Figure 7). They were mounted with the concave surface on top and the cutting edges forming a 60° angle. Sweeps were constructed in 31- and 38-inch widths, both of which functioned satisfactorily. Action upon the soil was slightly greater than that of Pence sweeps but not so severe as that of plow-lay sweeps.

Blade tiller

The blade tiller was constructed from an 8-foot grader blade mounted on plates by which it was attached to shanks of a three-bottom lister (Figure 10). This blade operated with the convex surface on top and lifted the soil slightly more than 2 inches. It entered bare soil readily and maintained uniform cutting, even under dry conditions, but it did not perform satisfactorily in heavy residue. Action upon the soil was similar to that of Raydex sweeps.

Disk tiller

Disk harrows or one-way wheatland disks when properly set gave fair results in obtaining mulch culture tillage. One-ways, equipped with small shallow disks, were much less effective in covering trash than deep-cup disk machines. Disks of any design, when used on dry soil, may cause the surface to become highly pulverized. Rolling tools were satisfactory when used under proper moisture conditions.

Draft Requirements

Drafts of eight different implements were determined. Tools used were adjusted to operate at approximately the same depth and were pulled at comparable speed. Each tool was operated under two test runs of 300 feet each on very uniform soil. The time of travel over this distance was determined with a stop watch. The depth of penetration was measured. Soil samples were taken on either side of the furrow at three locations for moisture determinations. Drafts were measured by a Szekely recording dynamometer. Detailed results of the tests are shown in Table 12. Comparative draft requirements for different tools were determined by calculating pounds pull per square inch of furrow slice (Figure 11). Reasons for the high draft obtained with Raydex sweeps are not readily apparent. Drafts of lister and basin lister were based upon the quantity of soil moved out of furrows.

Conservation of Runoff Water

Effectiveness of tillage and land treatment practices was determined by measuring rainfall and runoff from all experimental areas except those occupied by terraces with closed ends. In other investigations (2 and 7) intensity was found to be the most important rainfall factor causing runoff. These comparisons, therefore, are based subsequently on percentage of annual runoff and on amount of runoff from high intensity rains resulting in water losses from experimental areas. Runoff water was measured with type H flumes and Friez FW-1 waterstage recorders.

CONTINUOUS TILLAGE

Amounts of runoff water from plots in continuous tillage are recorded in Table 13. On unterraced plots, it was measured at a point immediately below the plot as near as possible to the natural area of concentration. Water was conducted to the measuring unit by converging dikes, which had a grade of 0.3 foot per 100 feet. Runoff was measured from terraced plots by placing a flume in the channel at the open end.

Runoff water losses were reduced by terraces and contour cultivation. Where all tillage operations for seedbed preparation and planting were made up and down the slope, annual runoff was least from mulched areas and greatest from listed land (Figure 12). Runoff on basin listed plots was about the same as that from plowed, probably because the dams and furrows often broke during heavy rains (Figure 13). Both listing and basin listing on contour conserved more water than moldboard plowing on contour. Where a combination of terraces and contour cultivation was used, the average annual amount of runoff was reduced 35.4 percent as compared to that from up and down slope methods (Table 3).

July rainfall is usually low, averaging only 2.56 inches (Table 9), but in 1950 it was 8.66 inches. There were 15 separate rains, the most critical of which fell on wet soil. This particular rain had 5-, 15-, 30-, and 60-minute intensities of 7.20, 4.02, 3.36, and 2.34 inches per hour, respectively. Sheet and gully erosion was severe on all plowed plots (Figure 14). The soil was severely deflocculated. The stubble mulch plots (Figure 15) showed little or no sign of erosion and had good surface structure. In fact, most of them were relatively fluffy and had flocculated conditions.

ROTATION TILLAGE

Runoff water losses from the rotation tillage areas are given in Table 14. Measuring instruments were located immediately below each watershed at the point of natural concentration. Water losses were highest from one-way plowed areas and lowest from basin listed land, which indicates that both mulches and rough surfaces conserve water (Figure 16).

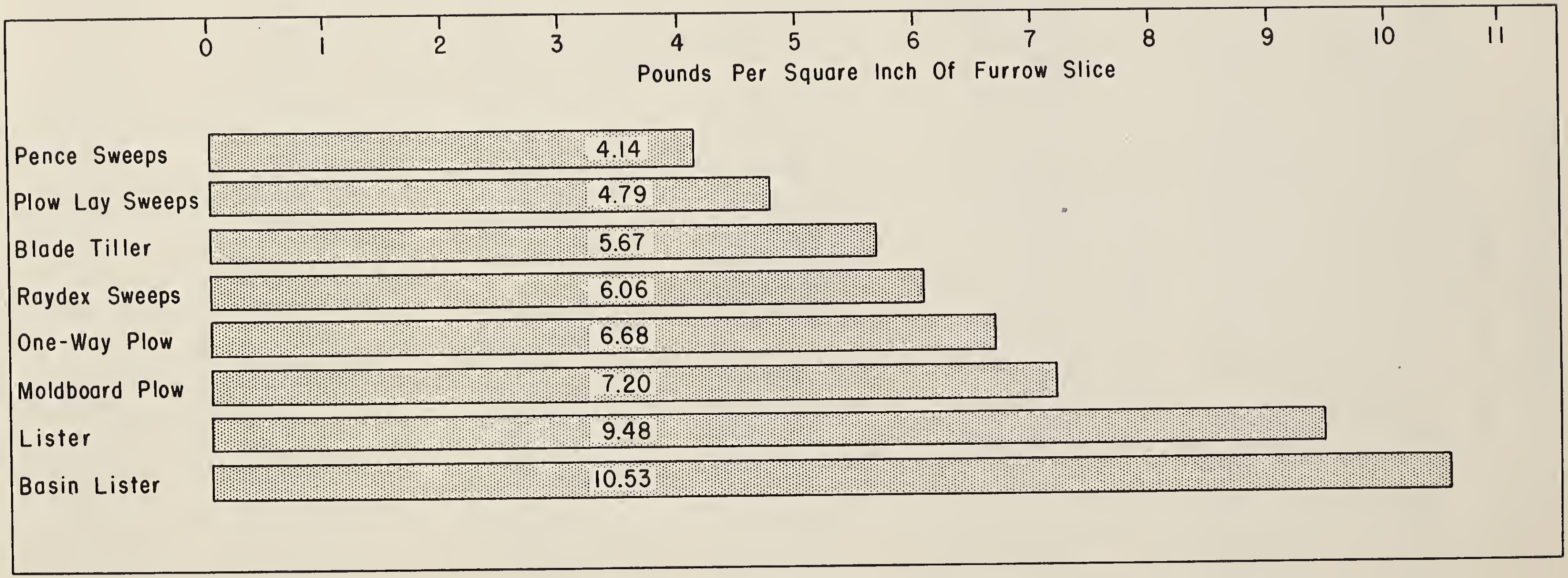
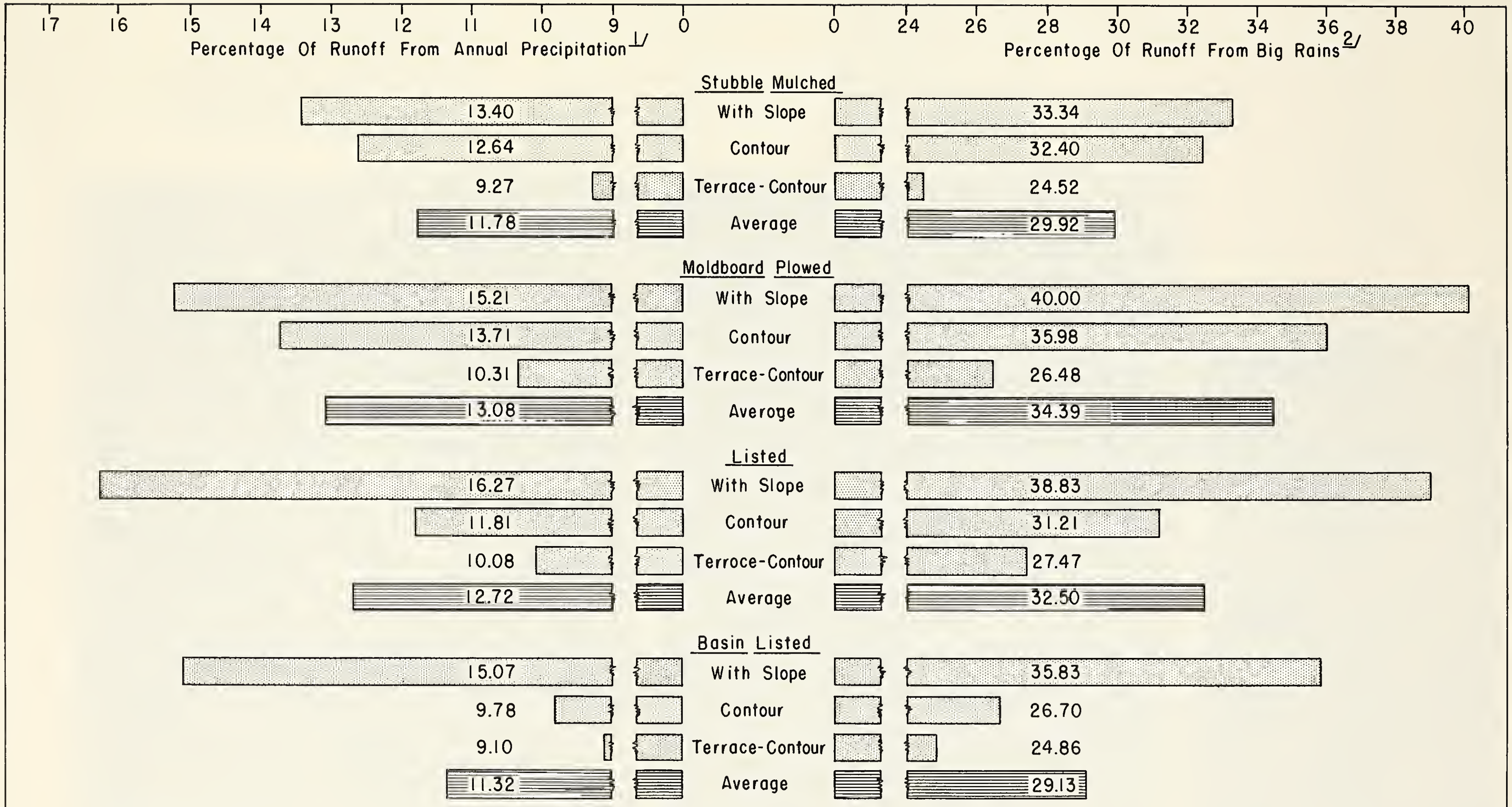


FIGURE 11.--Draft requirements of stubble mulch and other wheatland tillage tools.



1/ Each figure recorded represents an averoge of annual meosurements on three plots from 1942 through 1951 cropping seasons.

2/ Each figure recorded represents an average of measurements on the same plots af the roins causing runoff from oll plots an the stotion.

FIGURE 12. --Runoff water from plots tilled by continuous methods.

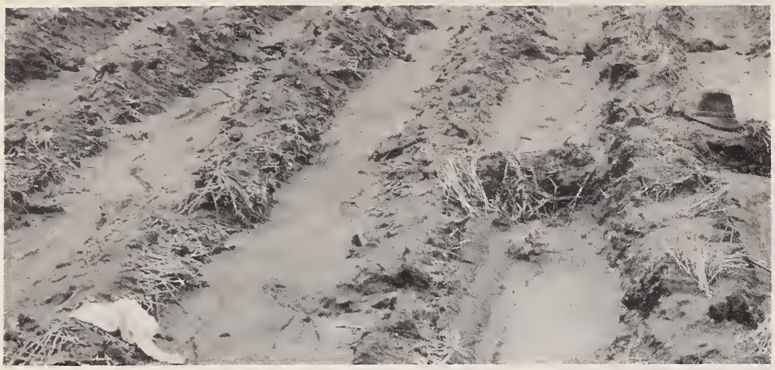


FIGURE 13. --Basin listing with land slope.

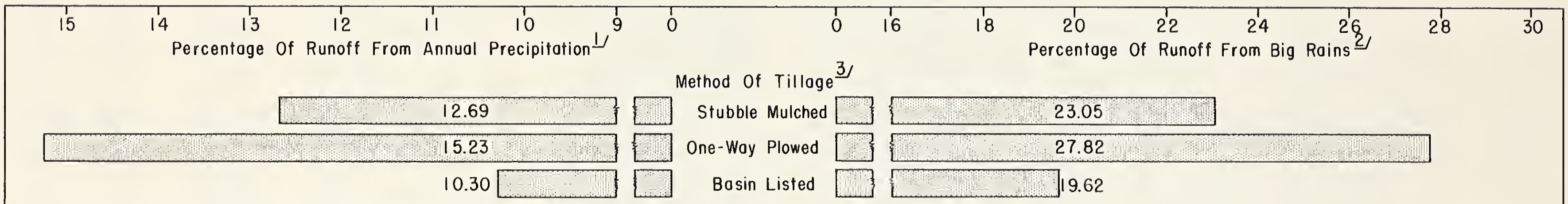
Dams made by basin listing up and down the slope often broke during heavy rains.

FIGURE 14.--Erosion on plowed, terraced, and contour cultivated land.

This picture was taken following the heavy rains of July 1950, on the Wheatland Conservation Experiment Station. It was made on a plowed, terraced, and contour cultivated plot.

FIGURE 15. --Mulches conserve soil and water.

This picture was also taken on the Wheatland Conservation Experiment Station in July 1950, following the heavy rainfall. It was made on a stubble mulched, terraced, and contour cultivated plot. Mulch tillage has been conducted on this particular plot continuously since 1939. An excellent dark surface soil, with lots of raw organic matter, good tilth, and aggregation, has developed.



[1] Each figure recorded represents an average of annual measurements on 3 watersheds from 1942 through 1951.
[2] Each figure recorded represents an average of measurements from the same watersheds of storms that caused runoff from all the areas on the station.
[3] All areas were cultivated on the contour.

FIGURE 16. --Runoff water from watersheds tilled by rotation methods.

Table 3. Effect of terraces and direction of cultivation on runoff at Wheatland Station, Cherokee, Okla., 1942-51

Terraces and direction of cultivation	Runoff Percent of Precipitation	
	Annual average	Difference percent reduction
With slope	14.99	
On contour		
Unterraced	11.98	20.0
Terraced	9.69	35.4

Conservation of Soil Moisture

Moisture content of the soil was measured at three different times during each cropping season. Sampling periods were just after wheat seeding in the fall, at beginning of spring growth, and immediately after harvest. Soil samples were chosen by restricted randomization on each continuous and rotation tillage area. They were taken with a soil tube, at one-foot intervals, to a depth of three feet. Total moisture was determined by oven drying. Data from experiments in continuous tillage are recorded in Table 15 and those from rotation tillage, in Table 16.

CONTINUOUS TILLAGE

The moisture content of the soil, tilled by continuous tillage methods, is shown in Figure 17. There was little or no difference in results obtained, except that plots listed on contour contained more moisture at seeding time than those moldboard plowed.

ROTATION TILLAGE

The moisture content of soil, tilled by rotation tillage methods, is given in Figure 18. Moisture in the soil under stubble mulching was about the same as that for one-way plowing and basin listing.

MOISTURE CONSUMED BY WEEDS

Mulched land has consistently contained a heavy growth of cheat and weeds, which was severe competition to the wheat (Figure 19). Weed growth on the different areas was collected, air-dried, and weighed (Table 17). There was an average of 5.6 times more weeds on the continuously mulched areas than on the plowed land. Although stand counts were not made, observations showed that there was considerably more volunteer wheat on the stubble-mulched plots.

Where tillage methods were rotated, weeds have not been a serious problem. It is reasonable to assume that the extra growth of volunteer wheat and weeds consumed moisture on stubble mulched land. Similar results are reported by Finnell (6) in his study of farmer experience with crop residue disposition in the southern winter wheat area of the Great Plains.

Effect on Yield of Wheat

Crop yields were determined on both continuous and rotation tillage areas. Measurements included production of grain and straw and height of plants. Grain and straw yields

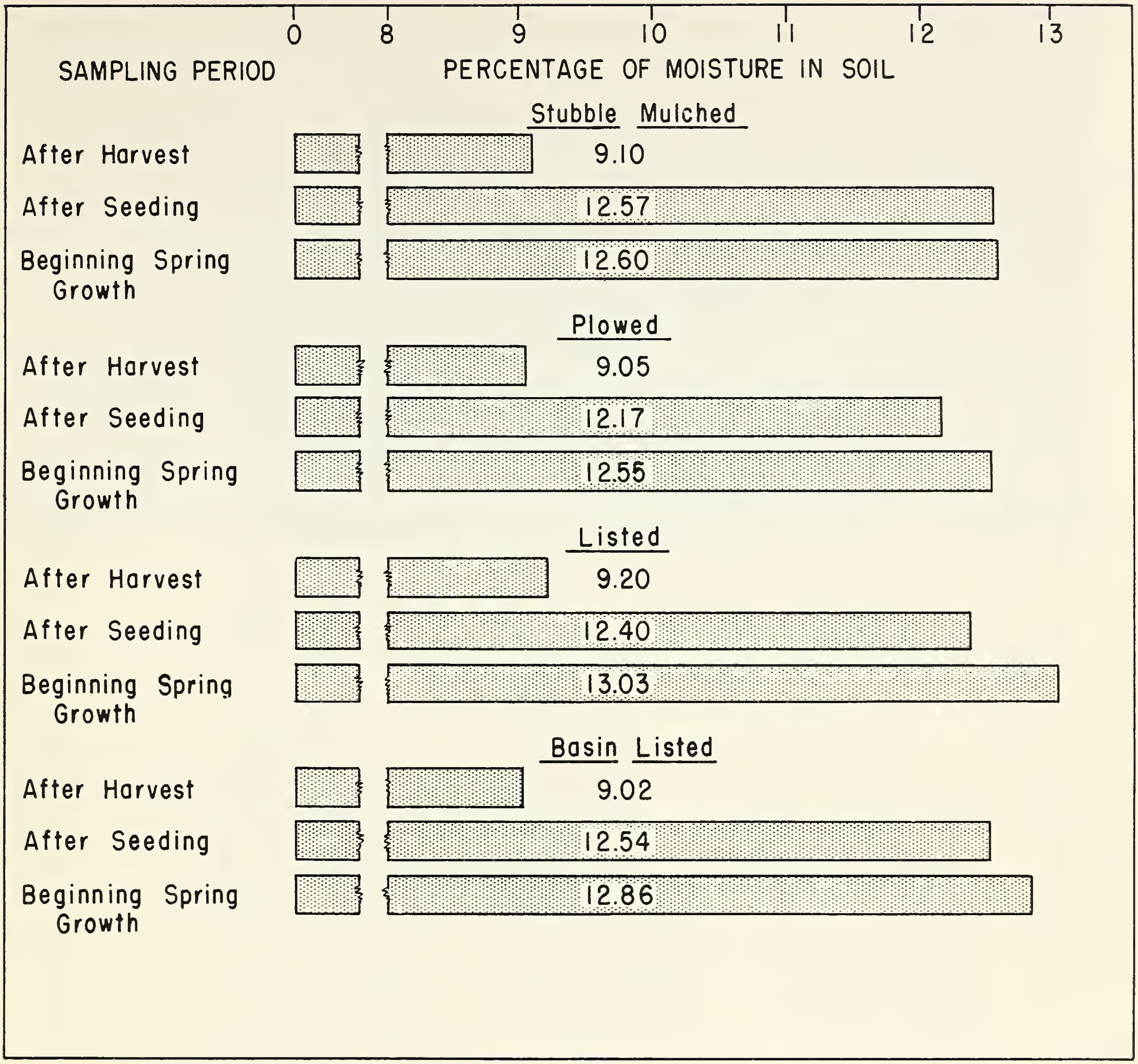


FIGURE 17. -- Average moisture content of soil at different times during the cropping season on plots tilled by continuous methods.

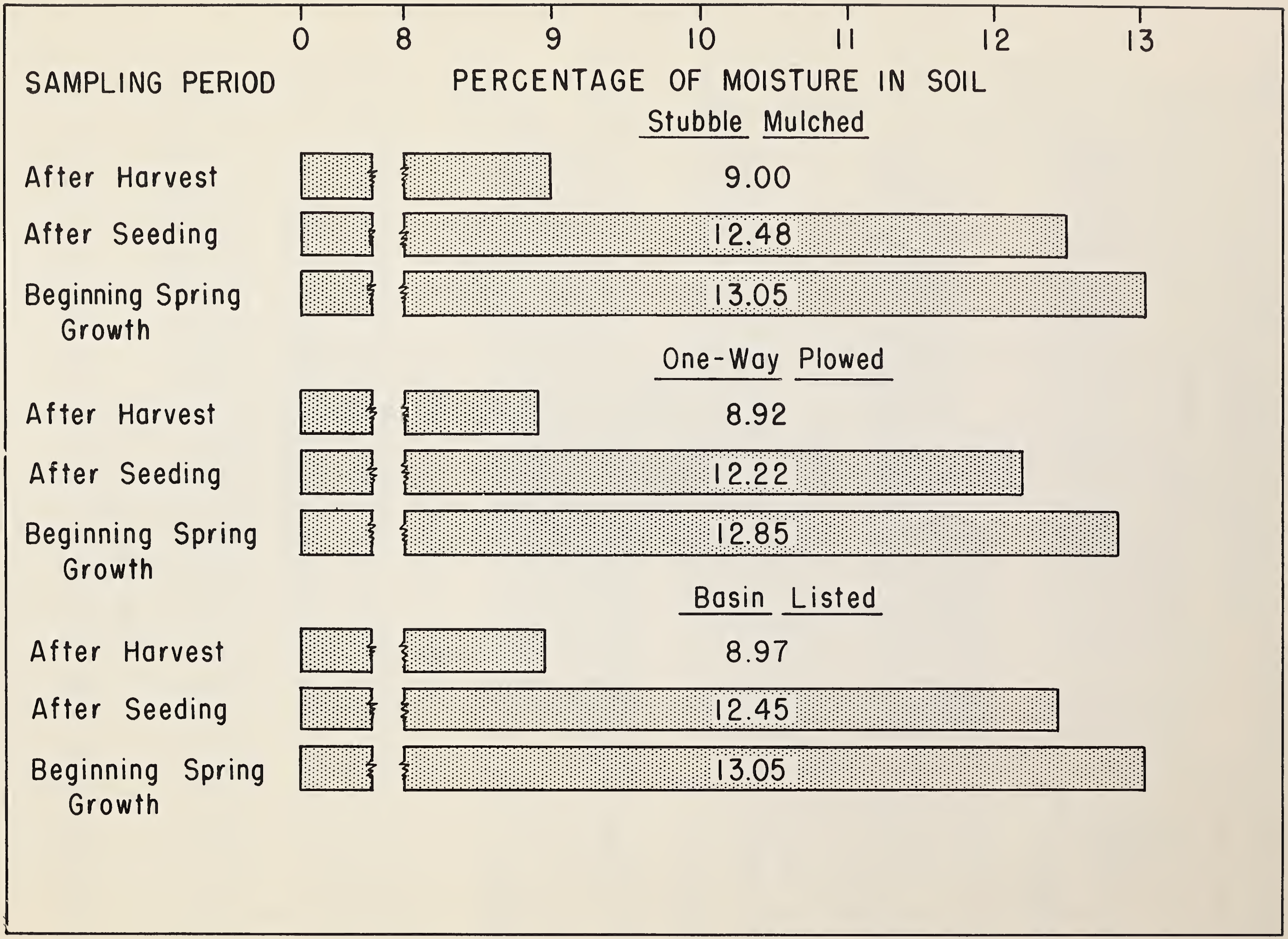


FIGURE 18. --Moisture content of soil at different times during cropping season on watersheds tilled by rotation methods.

FIGURE 19.--Weeds and cheat in wheat on stubble mulch plot 3A in 1945.

from continuously tilled plots are reported in Table 18, and those from rotation tillage, in Table 19.

TERRACES AND CONTOUR CULTIVATION

The terraced and contour cultivated plots produced only an average of 1.1 bushels per acre more wheat than unterraced land (Table 4). The first and second year after terraces were built, the yield was lower on terraced and contour cultivated plots than it was on plots cultivated with the slope. Beginning with the third year, yields were slightly higher on terraced plots, except in 1949 which was an abnormally wet season.

Table 4. Effect of terraces and contour cultivation on wheat yields

Year	Difference in yield from plots cultivated with slope[1] (bushels per acre)	
	Cultivated on contour	Terraced and cultivated on contour[2]
1942	-0.5	-1.9
1943	0.7	-0.5
1944	1.5	1.7
1945	1.4	1.3
1946	3.0	2.8
1947[3]	0.7	1.2
1948	0.6	2.0
1949	0.8	0.0
1950[4]	1.9	3.0
1951	1.7	1.8
Average	1.2	1.1

See footnotes on following page.

Under continuous tillage, the highest average yield of wheat and straw was produced on plowed land and the lowest on stubble-mulched plots (Figure 20) During the 10-year period, plowed plots have produced a total of 40 bushels per acre more wheat than mulched. Yields on listed and basin-listed land have been about the same. They were only slightly less than those from plowed.

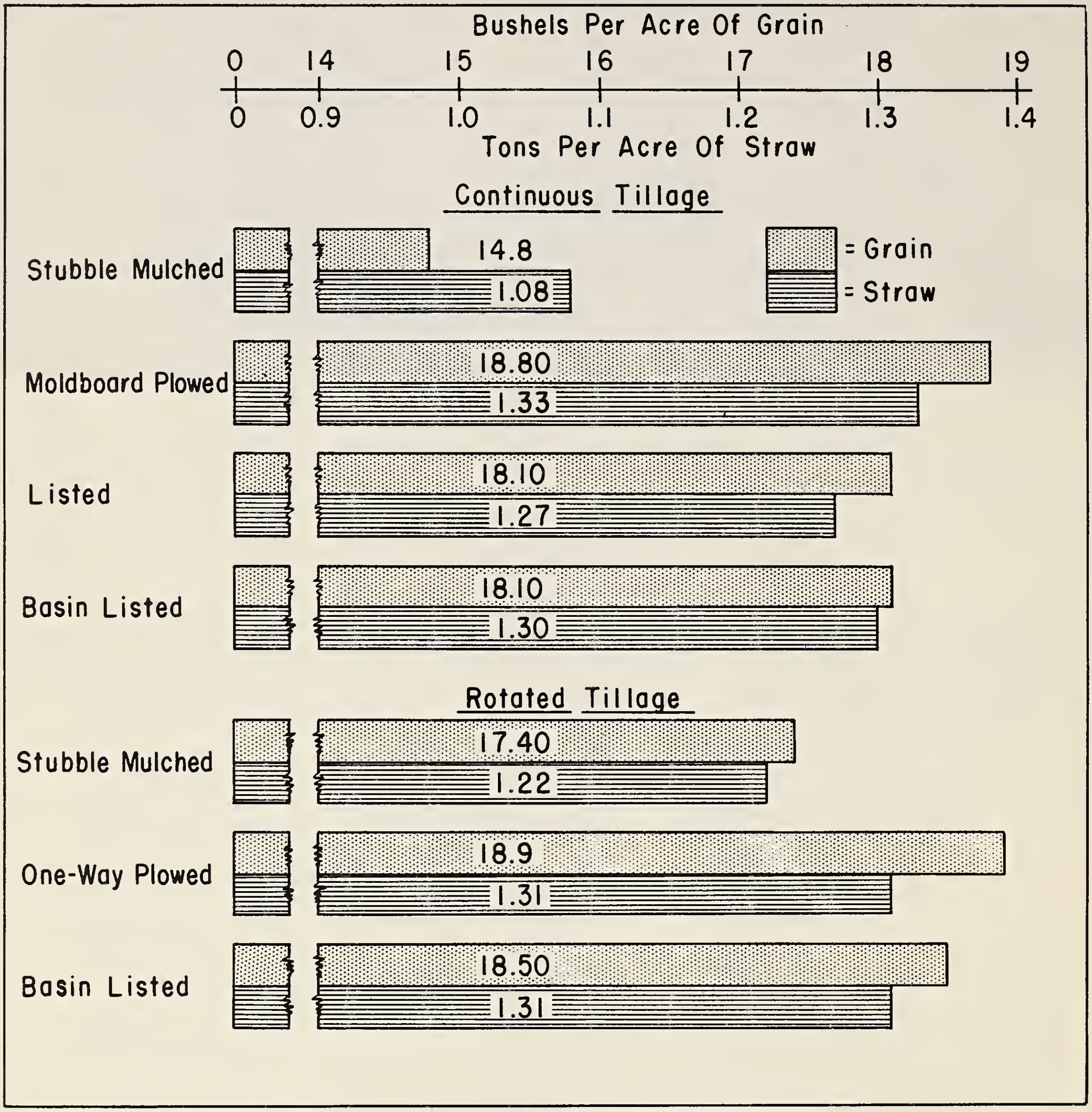


FIGURE 20.--Grain and straw yields of wheat from both continuous and rotation methods of tillage.

FOOTNOTES TO TABLE 4

[1] This data was obtained by subtracting yield on plots cultivated with slope, from those on contour and those terraced and contour cultivated.

[2] Short level terraces, one end open.

[3] The rainfall was below average during summer, fall, and winter, but above average during spring growing season.

[4] There was good subsoil moisture at seeding time. Precipitation, however, was extremely low during fall, winter, and early spring months, but rainfall was slightly above average in May.

The height of plants was recorded immediately before harvest (Table 20). Results show that wheat on mulched plots did not grow so tall as that on plowed, listed, or basin-listed land.

ROTATION TILLAGE

Where rotation tillage was used, the highest average yield of wheat was produced on one-way plowed and the lowest on stubble-mulched land (Figure 20). During the 10-year period, plowed land produced 16 bushels per acre more than mulched. Yields from basin-listed plots under this system of tillage were only slightly less than those from one-way plowed land.

FERTILIZER IMPROVES GROUND COVER

As the studies advanced, it became apparent that supplementary treatments were necessary in connection with stubble mulch culture. Therefore, an effort was made to increase the growth of small grain and produce a better land cover by applying various amounts of fertilizer (Table 5). These studies were made during a 5-year period on small plots located at different sites each year. Site selections were made in March on areas relatively free of weeds. Wheat responded only slightly to small amounts of nitrogen, but the greatest increase appeared to be on stubble-mulched plots.

Table 5. Effect of various amounts of nitrogen on yield of wheat from stubble-mulched and plowed land

Pounds of nitrogen per acre[1]	Yield of wheat per acre[2]			
	Stubble-mulched land		Plowed land	
	Grain bushels	Straw tons	Grain bushels	Straw tons
None.............	15.4	1.05	16.2	1.01
4................	16.2	1.09	16.9	0.98
8................	17.9	1.12	17.4	1.18
12...............	18.0	1.27	17.4	1.20
16...............	17.7	1.19	16.9	1.20
24...............	19.1	1.30	19.0	1.26

[1] Applied in March about the time plants began to grow.
[2] Average of 6 years, 1945-50, from duplicate treatments on small plots located at different sites each year.

In another experiment, best results were obtained from a combination of superphosphate and nitrogen (Table 6). Superphosphate and winter legumes also increased yields of wheat (Figure 21). Superphosphate alone increased the yield about 40 percent and the combination of superphosphate and nitrogen increased it 58 percent. Straw residues were plowed under in these trials.

The increased production of straw and legumes developed a better land cover. The wheat receiving phosphorus made a more rapid growth in the spring, at a time when erosion was severe, and matured earlier.

FIGURE 21.--Legumes and commercial fertilizer increased wheat yields at Wheatland Station.

This plot of Austrian winter peas was fertilized with 250 pounds superphosphate (0-20-0) per acre. The per acre yield of peas was 17.6 bushels and wheat, the following year, made 28.8 bushels. The adjacent unfertilized check plot made only 7.9 bushels of wheat per acre.

Table 6. Effect of fertilizer and winter legumes on yield of wheat

Treatment[1]	Yield per acre[2]	
	Straw (Tons)	Grain (Bushels)
Commercial Fertilizer		
Five-year average, 1946-1950		
Check	0.92	14.7
Superphosphate	1.15	18.4
Superphosphate and nitrogen	1.52	23.2
Nitrogen (fall)	1.04	15.5
Nitrogen (spring)	0.93	14.3
Fertilizer and Legumes		
Four-year average, 1947-1950		
Check	0.89	13.2
Wheat following winter peas[3]	1.04	16.2
Wheat following winter peas and superphosphate[3]	1.30	19.0
Two-year average, 1949-1950		
Check	0.85	14.1
Wheat, winter peas, and superphosphate[3]	1.01	18.4
Wheat, vetch, and superphosphate[4]	1.09	19.2

[1] Superphosphate (0-20-0)--250 pounds and nitrogen--33 pounds per acre. Wheat planted with a 10-inch semideep furrow disk drill.

[2] Averages of triplicate treatments.

[3] Yields per acre of winter peas in 1947 were as follows: (a) no treatment--0.96 tons of hay and 14.5 bushels of seed; (b) with superphosphate--1.14 tons of hay and 17.6 bushels of seed. The crop failed in 1948, 1949, and 1950.

[4] Vetch failed on unfertilized plots in 1950.

DISCUSSION

In considering results of these experiments, it should be borne in mind that they were initiated in 1942. At that time, emphasis was placed on means of reducing runoff and conserving moisture for plant growth on land in continuous wheat. Suitable techniques for stubble-mulch tillage were undeveloped and emphasis was not placed on methods of accomplishing it. However, stubble mulch culture, when compared to plowing and listing, was valuable for preventing erosion and reducing runoff, but the yield of wheat was lower than from other methods of tillage. Mulched land has consistently contained a heavy growth of weeds (Table 17) and wheat plants have been attacked by an infestation of foot-rot or disease (Table 21). There was an average of 8.8 times more white heads on continuously stubble mulched areas than on plowed land; but foot-rot, etc., were not serious problems where the tillage was rotated. During 1943, some straw worm damage was also observed on mulched plots. These results, therefore, indicate the problems encountered in adapting stubble mulch tillage to continuous wheat culture on soils of this area.

Weeds and Diseases

The yield of wheat produced on areas tilled by continuous methods is compared with amount of weeds and white heads of wheat in Figure 22. From these data, it is apparent that the competition of weeds and plant diseases was a factor in depressing yields of wheat on mulched land. It is also evident that both weeds and diseases were controlled by clean cultivation. Weeds were also controlled by late tillage during wet falls. Data in Table 7 indicate that when rainfall was extremely low in September and wheat was seeded in dry soil, weeds the following season were a problem. For that reason, it was practically impossible to control weeds on mulched land unless there was sufficient moisture with cool temperatures to germinate weed seed before wheat was planted.

Table 7. Comparison of September rainfall with weeds produced in wheat on stubble mulched plots

Year	September rainfall Inches	Weeds per acre Pounds
1943	2.76	237
1944	0.80	38
1945	2.61	216
1946	5.68	0
1947	0.49	231
1948	0.00	811
1949	0.42	750
1950	3.18	0
1951	1.32	0

Method of Tillage

Tillage necessary for adequate seedbed preparation includes covering of shattered grain and weed seed and control of weeds. The use of a combination of tools seemed to have an advantage for this purpose. During seasons of extremely heavy growth of straw, it was desirable to cultivate the soil shallow during the first tillage operation with a disk

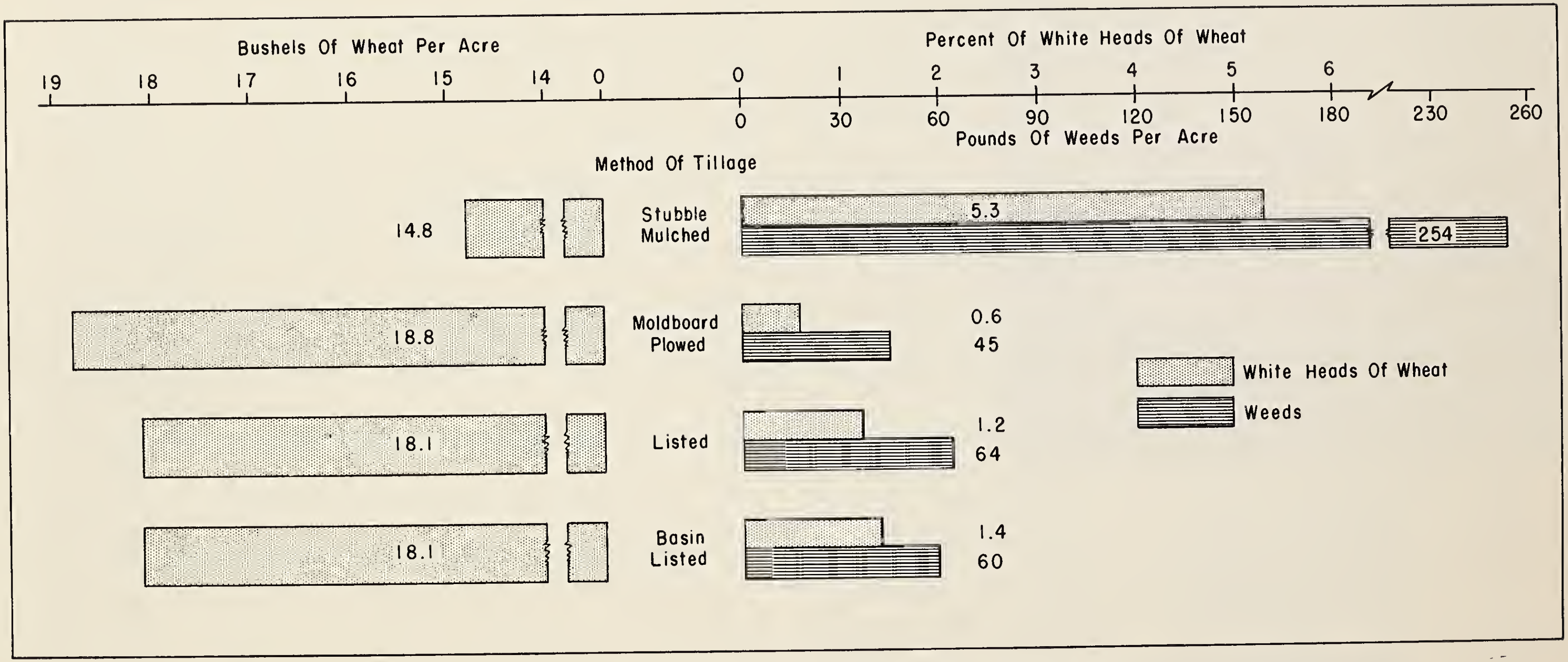
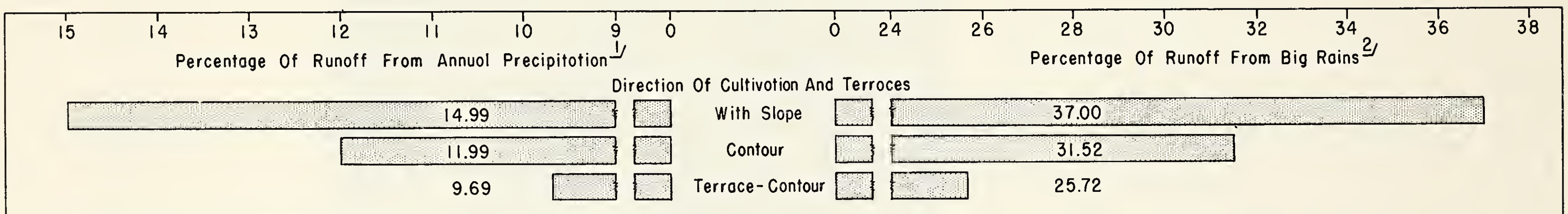


FIGURE 22. 11Comparisons of yield of wheat to amounts of weeds and white heads of wheat produced on plots tilled by continuous methods.



[1] Each figure recorded represents an average of annual measurements on 12 plots from 1942 through 1951.
[2] Each figure recorded represents an average of measurements from the same plots of storms that caused runoff from all the plots on the station.

FIGURE 23. --Runoff water from terraced and unterraced land

type tiller. When yields of straw were average or below, large sweeps agitated the soil and did a fairly good job of covering shattered grain and weed seeds. Weed growth under normal rainfall conditions was controlled successfully with sweep tillers. However, during extremely wet seasons, annual grass and other weeds were difficult to kill with sweeps; and during extremely dry seasons the surface soil became very loose.

The method of tillage for seedbed preparation apparently should be flexible in order to take advantage of moisture conditions. When soil moisture conditions are favorable following harvest, crop residue may be worked into the top soil. If dry weather prevails, immediate one-way disking or other surface tillage appears to be justified in the area represented by this station.

Combinations of Practices Needed

Water conservation for wheat production appears to require a combination of many practices (2 and 3). On deep, permeable soils of this area, it appears that terraces may be designed to conserve moisture (5). Contour cultivation conserves water as shown by Figure 23; however, contouring alone was not enough for controlling erosion on steep slopes. On land of this nature, best results were obtained from a combination of terraces and contour cultivation. The water saved (Figure 24) was stored in the soil and did not contribute to flood waters of local streams. Consequently, cultivation and cropping systems (4) should be planned to distribute uniformly and use economically the rainfall to produce crops and maintain a protective cover.

FIGURE 24. --Listing on contour holds water in field.

Terraces and contour cultivation conserved 35.4 percent more moisture than did cultivation up and down the slope

SUMMARY

Stubble mulch and other cultural practices for moisture conservation and wheat production were studied on deep, permeable, and fertile soil, with rolling topography, at the Wheatland Conservation Experiment Station in Alfalfa County, near Cherokee, Okla., from 1942 to 1951. The experiment was designed to devise means of reducing runoff water and conserving moisture for wheat production. Investigations consisted of a comparison of different methods of seedbed preparation, including both continuous and rotation tillage.

Continuous tillage experiments were designed to evaluate effectiveness of plowing, listing, basin listing, and stubble-mulch tillage practices on terraced and unterraced land. Rotation methods compared the effectiveness of a 3-year sequence of one-way plowing, basin listing, and stubble-mulch tillage on contour cultivated land. Large sweeps seemed to be the best tool for stubble-mulch tillage.

Runoff water from continuous tillage practices was least from mulched land and greatest from listed, where all cultivation was conducted up and down the slope. Both listing and basin listing reduced runoff water when listing followed the contour. Where a combination of terraces and contour cultivation was used, the average annual amount of runoff water was reduced 35.4 percent. Mulches and rough surfaces also conserved water on rotation tillage areas. However, there was little or no difference in moisture content stored in the soil under different methods of tillage, except that plots listed on the contour contained more moisture at seeding time than those moldboard plowed.

Terraces and contour cultivation only increased the yield of wheat an average of 1.1 bushels per acre. The highest yield was produced on plowed land and the lowest on mulched, in continuous tillage experiments. Where rotation tillage was used, the highest yield of wheat was obtained from one-way plowed land and the lowest on mulched. Weeds and foot-rot or disease were severe competition to wheat on mulched land, but they were not a serious problem where the tillage was rotated.

Wheat responded only slightly to small amounts of nitrogen fertilizer, but the greatest increase was on stubble-mulched land. Superphosphate alone increased the yield of wheat about 40 percent and the combination of superphosphate and nitrogen increased it 58 percent. Winter legumes in combination with superphosphate also increased wheat yields.

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APPENDIX

Table 8. Annual Meteorological Data Recorded at Wheatland Station

Year	Temperature degrees Fahrenheit				Average humidity percent		Wind movement miles per hour[1]			Evaporation total inches[2]	Precipitation			
			Average								No. of storms		Total inches	Departure from ave. inches[4]
	High	Low	Max.	Min.	Max.	Min.	High	Low	Average		Total	Causing runoff[3]		
1942	107	8	95	23	90	62	21.5	0.2	6.5	49.430	61	15	30.03	+4.45
1943	99	0	67	46	90	59	37.9	0.8	6.8	54.766	61	6	20.28	-5.64
1944	110	3	68	48	87	54	21.4	0.4	6.4	60.903	49	8	20.40	-5.52
1945	106	12	92	28	87	54	29.5	0.1	6.1	49.302	59	14	34.35	+8.61
1946	104	4	92	23	86	51	36.3	1.6	6.6	55.294	43	15	23.70	-2.14
1947	116	-18	70	45	88	57	31.0	1.1	7.1	55.063	48	16	24.61	-1.27
1948	112	-4	101	20	84	54	19.8	0.1	6.6	65.948	46	7	17.88	-7.81
1949	110	1	91	17	84	54	40.0	0.5	6.2	47.986	62	31	42.10	+15.79
1950	111	-1	72	44	82	48	18.7	0.9	6.9	50.862	47	8	18.23	-8.11
1951	102	-11	68	43	81	50	28.1	1.6	6.5	46.138	71	22	38.50	+11.95
Yearly	116	-18	82	34	86	54	40.0	0.1	6.6	53.569	55	14	27.01	+0.46

1 Measured at about 2.0 feet above ground level.
2 Warm season only. Measured from open metal tank as used by Weather Bureau.
3 Runoff from Plot 28-A, listed with slope.
4 Based on Weather Bureau records in Cherokee, Okla., since 1915.

Table 9. Monthly Meteorological Data at Wheatland Station, 1942-1951

Month	Temperature degrees Fahrenheit				Average humidity percent		Wind movement miles per hour[1]			Evaporation total inches[2]	Precipitation Averages			
			Average								No. of storms		Total inches	Departure from ave. inches[4]
	High	Low	Max.	Min.	Max.	Min.	High	Low	Average		Total	Causing runoff[3]		
July	112	52	93	68	85	49	19.6	1.7	5.8	10.418	5.6	0.8	2.56	+0.42
August	116	46	92	68	83	50	14.4	0.9	5.5	9.923	6.8	2.2	3.70	+0.43
September	116	32	84	59	83	50	19.8	1.0	6.5	8.021	4.5	0.9	1.93	-0.79
October	101	22	74	49	87	54	37.9	1.1	6.1	4.868	4.8	1.0	2.75	+0.45
November	85	9	58	34	86	55	30.5	0.1	6.5		2.2	0.2	0.86	-0.61
December	80	0	47	27	90	62	36.6	1.1	6.1		1.9	0.3	1.01	+0.04
January	79	-18	45	24	87	57	17.0	0.6	6.6		2.5	0.1	0.68	-0.19
February	84	-11	50	28	85	58	21.5	0.2	7.1		2.7	0.6	1.18	+0.29
March	93	-4	57	32	86	54	31.0	0.5	8.6		3.7	1.3	1.41	-0.11
April	98	22	68	43	86	55	40.0	0.8	7.6	5.454	5.3	1.9	3.18	+0.24
May	106	30	76	53	87	56	28.1	0.6	6.1	6.363	8.1	3.2	3.94	+0.26
June	112	41	88	64	86	51	16.9	0.1	6.2	8.522	6.6	1.7	3.81	+0.02
Yearly	116	-18	65	43	86	54	40.0	0.1	6.6	53.569	54.7	14.2	27.01	+0.46

1 Measured at about 2.0 feet above ground level.
2 Warm season only. Measured from open metal tank as used by Weather Bureau.
3 Runoff from Plot 28-A, listed with slope.
4 Based on Weather Bureau records in Cherokee, Oklahoma, since 1915.

Table 10. Treatment and Physical Characteristics on Continuous Tillage Plots

Plot	Tillage	Area acres	Slope percent	Direction of tillage and seeding
1A......	Stubble Mulched	2.469	2.14	Unterraced, contour
2A......	do	1.913	2.25	Unterraced, with slope
3A......	do	1.864	2.34	Terraced, closed end, contour
4A......	do	2.236	1.86	Terraced, open end, contour
5A......	Moldboard Plowed	2.189	2.23	Terraced, closed end, contour
6A......	do	1.385	2.69	Terraced, open end, contour
7A......	do	1.797	2.94	Unterraced, contour
8A......	do	1.644	2.74	Unterraced, with slope
9A......	Basin Listed	2.024	2.72	Unterraced, contour
10A......	do	2.653	2.25	Terraced, open end, contour
11A......	do	1.324	2.94	Terraced, closed end, contour
12A......	do	2.105	2.43	Unterraced, with slope
13A......	Listed	1.971	2.19	Unterraced, with slope
14A......	do	1.935	2.52	Terraced, closed end, contour
15A......	do	1.700	2.40	Terraced, open end, contour
16A......	do	1.725	2.64	Unterraced, contour
17A......	Stubble Mulched	1.556	2.46	Unterraced, with slope
18A......	do	2.416	2.05	Unterraced, contour
19A......	do	2.088	2.43	Terraced, closed end, contour
20A......	do	1.599	2.42	Terraced, open end, contour
21A......	Moldboard Plowed	1.456	2.20	Terraced, closed end, contour
22A......	do	1.148	3.00	Unterraced, contour
23A......	do	1.070	2.80	Terraced, open end, contour
24A......	do	2.689	1.71	Unterraced, with slope
25A......	Listed	2.847	2.15	Terraced, open end, contour
26A......	do	1.462	2.51	Unterraced, contour
27A......	do	4.301	1.95	Terraced, closed end, contour
28A......	do	1.736	2.46	Unterraced, with slope
29A......	Basin Listed	1.582	2.32	Unterraced, with slope
30A......	do	2.577	1.84	Unterraced, contour
31A......	do	3.098	1.88	Terraced, open end, contour
32A......	do	3.366	1.48	Terraced, closed end, contour
1B......	Listed	.575	5.29	Terraced, closed end, contour
2B......	do	.608	5.08	Terraced, open end, contour
3B......	do	1.901	3.20	Unterraced, contour
4B......	do	1.313	3.41	Unterraced, with slope
5B......	Basin Listed	1.235	3.81	Terraced, open end, contour
6B......	do	1.340	3.80	Unterraced, contour
7B......	do	.917	4.13	Terraced, closed end, contour
8B......	do	1.105	4.05	Unterraced, with slope
9B......	Stubble Mulched	.793	3.91	Unterraced, contour
10B......	do	1.030	3.79	Unterraced, with slope
11B......	do	.966	4.14	Terraced, open end, contour
12B......	do	1.368	4.29	Terraced, closed end, contour
13B......	Moldboard Plowed	1.139	3.89	Unterraced, with slope
14B......	do	.505	5.09	Terraced, closed end, contour
15B......	do	.760	4.98	Unterraced, contour
16B......	do	.820	3.96	Terraced, open end, contour

Table 11. Treatments and Physical Characteristics of Rotation Tillage[1]

Watershed	1	2	5	3	4	7	6	8	9
Area acres	2.231	4.822	7.852	8.296	4.351	1.988	1.754	4.718	8.509
Slope percent	2.78	2.22	1.50	2.19	2.46	2.24	2.52	1.71	1.89
<u>Year</u>									
1942........	One-way plowed			Stubble mulched			Basin listed		
1943........	Basin listed			One-way plowed			Stubble mulched		
1944........	Stubble mulched			Basin listed			One-way plowed		
1945........	One-way plowed			Stubble mulched			Basin listed		
1946........	Basin listed			One-way plowed			Stubble mulched		
1947........	Stubble mulched			Basin listed			One-way plowed		
1948........	One-way plowed			Stubble mulched			Basin listed		
1949........	Basin listed			One-way plowed			Stubble mulched		
1950........	Stubble mulched			Basin listed			One-way plowed		
1951........	One-way plowed			Stubble mulched			Basin listed		

[1] Land cultivated on contour.

Table 12. Draft Tests of Tillage Tools, 1943[1]

Tool	No. of units	Unit width inches	Width of cut inches	Depth of cut inches	Miles per hour	Draft--pounds			Soil moisture percent
						Total	Per foot width	Per square inch[2]	
Plow-lay sweeps	3	32	93.0	5.35	2.63	2,384	308	4.79	9.75
Pence sweeps	3	42	130.5	5.14	2.57	2,778	255	4.14	9.99
Raydex sweeps	2	38	100.5	4.80	2.61	2,919	348	6.06	10.11
Blade tiller	1	96	96.0	5.22	2.59	2,836	355	5.67	10.42
Lister	3	14	42.0	6.60	2.68	2,626	750	9.48	10.48
Basin lister	3	14	42.0	6.22	2.66	2,752	786	10.53	10.45
One-way plow[3]	1	72	73.5	4.68	2.58	2,296	375	6.68	10.60
Plow	2	14	28.0	5.65	2.98	1,140	489	7.20	9.93

1 Data are average for two runs of 300 feet each.
2 Pounds per square inch of furrow slice.
3 One-way wheatland disk plow, 26-inch disks with 4-inch cup.

Table 13. Effect of Different Methods of Continuous Tillage, Terraces and Direction of Cultivation on Runoff Water at Wheatland Station[1]

Year	Direction of cultivation and terraces	Percent of precipitation lost as runoff									
		STUBBLE MULCHED		PLOWED		LISTED		BASIN LISTED		AVERAGE	
		Annual	Big[2] rains	Annual	Big[2] rains	Annual	Big[2] rains	Annual	Big[2] rains	Annual	Big[2] rains
1942.......	With slope	16.07	40.15	15.50	39.96	14.11	35.69	14.89	40.70	15.14	39.13
	Contour	14.26	36.89	12.79	34.13	11.81	31.35	13.14	35.05	13.00	34.36
	Terrace-contour	8.64	22.85	8.61	23.02	9.79	26.18	9.40	25.26	9.11	24.33
	Average	12.99	33.30	12.30	32.37	11.90	31.07	12.48	33.67	12.42	32.61
1943.......	With slope	6.21	32.56	6.19	45.30	4.81	25.97	4.87	25.36	5.52	32.30
	Contour	5.59	30.42	4.15	30.59	3.80	29.49	4.03	27.95	4.39	29.61
	Terrace-contour	3.04	18.91	3.41	14.64	3.69	25.15	3.48	22.90	3.40	20.40
	Average	4.95	29.30	4.58	30.17	4.10	26.87	4.13	25.40	4.44	27.43
1944.......	With slope	13.68	49.69	14.67	53.61	15.00	54.88	14.06	48.89	14.36	51.80
	Contour	12.36	48.35	13.62	53.63	11.91	49.64	11.14	47.94	12.25	49.82
	Terrace-contour	9.29	29.08	8.13	35.33	11.58	47.77	10.28	45.89	9.82	42.00
	Average	11.78	45.70	12.14	47.54	12.83	50.69	11.83	47.60	12.14	47.81
1945.......	With slope	15.14	43.04	17.29	54.20	19.35	48.18	17.70	41.59	17.37	46.75
	Contour	14.98	45.17	17.20	53.33	10.96	34.41	7.49	26.48	12.65	39.85
	Terrace-contour	9.28	31.53	10.75	34.60	9.22	31.65	7.18	25.82	9.11	30.90
	Average	13.13	39.91	15.08	47.38	13.18	38.08	10.79	31.30	13.04	39.17
1946.......	With slope	13.60	28.59	15.30	32.47	22.82	42.10	21.02	41.83	18.19	36.25
	Contour	12.12	25.23	15.08	30.46	12.82	30.36	7.97	18.33	12.00	26.15
	Terrace-contour	7.92	16.55	10.00	23.72	10.18	25.61	8.89	20.52	9.25	21.60
	Average	11.21	23.46	13.46	28.88	15.27	32.76	12.63	26.89	13.14	28.00
1947........	With slope	7.42	18.56	8.31	18.25	10.26	22.56	10.28	23.50	9.07	20.72
	Contour	7.47	18.64	3.45	9.41	7.15	19.35	4.87	14.64	5.74	15.51
	Terrace-contour	3.52	10.05	3.27	8.95	6.60	17.86	4.89	14.45	4.57	12.83
	Average	6.14	15.75	5.01	12.20	8.00	19.93	6.68	17.53	6.46	16.35

Table 13. Effect of Different Methods of Continuous Tillage, Terraces and Direction of Cultivation on Runoff Water at Wheatland Station[1]--Continued

Year	Direction of cultivation and terraces	Percent of precipitation lost as runoff									
		STUBBLE MULCHED		PLOWED		LISTED		BASIN LISTED		AVERAGE	
		Annual	Big[2] rains	Annual	Big[2] rains	Annual	Big[2] rains	Annual	Big[2] rains	Annual	Big[2] rains
1948........	With slope	9.22	24.97	13.76	35.45	12.03	32.20	12.81	33.19	11.95	31.45
	Contour	9.17	25.36	9.96	25.95	9.44	25.05	8.91	25.44	9.37	25.45
	Terrace-contour	6.73	18.44	7.97	21.34	8.26	23.43	9.68	27.23	8.16	22.61
	Average	8.37	22.92	10.56	27.58	9.91	26.89	10.47	28.62	9.83	26.50
1949........	With slope	27.10	38.75	30.03	42.86	32.76	46.53	28.86	42.96	29.69	42.78
	Contour	25.21	38.42	28.66	41.81	26.90	42.67	23.26	38.45	26.00	40.34
	Terrace-contour	22.17	34.55	24.98	37.47	22.34	35.63	20.22	33.57	22.42	35.30
	Average	24.83	37.24	27.89	40.71	27.33	41.61	24.11	38.32	26.04	39.47
1950........	With slope	2.94	15.61	5.06	32.86	7.19	37.42	5.35	23.05	5.13	27.23
	Contour	2.53	13.08	4.57	30.57	1.55	9.20	0.29	0.75	2.24	13.40
	Terrace-contour	1.64	9.82	3.77	25.62	1.53	7.64	0.40	1.38	1.83	11.12
	Average	2.37	12.84	4.47	29.68	3.42	18.09	2.01	8.39	3.07	17.25
1951.......	With slope	22.63	41.48	25.98	45.02	24.39	42.81	20.90	37.27	23.47	41.64
	Contour	22.57	42.46	27.65	47.93	21.72	40.40	16.74	31.97	22.17	40.69
	Terrace-contour	20.49	38.42	22.26	40.16	17.67	33.75	16.54	31.60	19.24	35.98
	Average	21.90	40.79	25.30	44.37	21.26	38.99	18.06	33.61	21.63	39.44
Average.....	With slope	13.40	33.34	15.21	40.00	16.27	38.83	15.07	35.83	14.99	37.00
	Contour	12.62	32.40	13.71	35.98	11.81	31.21	9.78	26.70	11.98	31.52
	Terrace-contour	9.27	24.52	10.31	26.48	10.08	27.47	9.10	24.86	9.69	25.72
	Average	11.78	29.92	13.08	34.39	12.72	32.50	11.32	29.13	12.22	31.41

[1] Crop year July 1 to June 30.
[2] Average of high intensity rains that cause runoff from all plots.

Table 14. Effect of Different Methods of Rotation Tillage on Runoff Water at Wheatland Station[1]

Year	Percentage of precipitation lost as runoff					
	Annual			Big rains		
	Stubble mulched	Basin listed	Plowed	Stubble mulched	Basin listed	Plowed
1942	9.80	8.88	12.99	18.89	16.79	23.91
1943	1.28	3.71	5.41	4.68	12.91	19.29
1944	13.20	12.75	11.43	32.06	30.30	27.31
1945	15.23	8.23	16.52	27.94	15.70	28.90
1946	7.17	11.96	15.00	11.69	19.45	24.39
1947	9.68	4.44	6.30	18.89	8.73	11.68
1948	10.50	9.83	15.21	27.89	26.03	38.26
1949	30.60	25.32	36.46	39.79	33.85	47.62
1950	2.65	2.59	3.98	7.32	7.19	12.46
1951	26.83	15.32	28.96	41.39	25.21	44.33
Average	12.69	10.30	15.23	23.05	19.62	27.82

[1] Land cultivated on contour.

Table 15. Percent of Moisture in Different Foot-Intervals of Soil on Continuous Tillage Plots at Different Times during Cropping Seasons, 1942-51[1]

Method of tillage	Terraces and kind of cultivation	After harvest[2]				After seeding[3]				Beginning of spring growth[4]			
		First foot	Second foot	Third foot	Average	First foot	Second foot	Third foot	Average	First foot	Second foot	Third foot	Average
Stubble mulched	With slope	9.26	8.64	8.48	8.79	12.94	12.71	11.45	12.37	12.61	12.94	11.71	12.42
Do...........	Contour	9.53	9.02	8.52	9.02	12.99	12.78	11.47	12.41	12.71	12.90	11.70	12.44
Do...........	Terraced, open end, contour	9.07	8.65	8.34	8.69	13.03	12.73	11.10	12.29	12.85	12.61	11.33	12.26
Do...........	Terraced, closed end, contour	9.57	9.89	10.23	9.90	13.59	13.60	12.39	13.19	13.24	13.64	12.98	13.29
	Average	9.36	9.05	8.89	9.10	13.14	12.96	11.60	12.57	12.85	13.02	11.93	12.60
Plowed	With slope	9.38	8.92	8.19	8.83	12.18	12.46	11.26	11.97	12.26	12.75	11.74	12.25
Do...........	Contour	9.64	9.42	8.32	9.13	12.61	12.69	11.15	12.15	12.64	13.75	11.94	12.78
Do...........	Terraced, open end, contour	9.82	9.70	9.03	9.52	12.98	13.16	11.75	12.63	12.95	13.75	12.29	13.00
Do...........	Terraced, closed end, contour	9.17	8.93	8.03	8.71	12.46	12.25	11.09	11.93	12.55	12.44	11.55	12.18
	Average	9.50	9.24	8.39	9.05	12.56	12.64	11.31	12.17	12.60	13.17	11.88	12.55
Listed	With slope	9.07	8.51	9.02	8.87	12.68	12.62	11.35	12.22	13.18	13.38	12.46	13.01
Do...........	Contour	9.19	8.96	9.10	9.08	11.99	12.73	11.59	12.10	13.30	13.33	12.59	13.07
Do...........	Terraced, open end, contour	9.41	9.39	9.16	9.32	12.95	12.91	11.17	12.34	13.26	13.22	11.79	12.76
Do...........	Terraced, closed end, contour	9.88	9.46	9.32	9.55	13.20	13.31	12.31	12.94	13.58	13.82	12.40	13.27
	Average	9.39	9.08	9.15	9.20	12.70	12.89	11.61	12.40	13.33	13.44	12.31	13.03
Basin listed	With slope	8.92	8.92	9.22	9.02	12.56	13.09	11.53	12.39	12.88	13.48	12.29	12.88
Do...........	Contour	9.04	8.89	8.67	8.87	12.72	12.96	11.83	12.50	12.50	13.02	11.90	12.47
Do...........	Terraced, open end, contour	9.37	8.65	8.99	9.00	12.89	13.10	11.90	12.63	13.12	13.52	12.63	13.09
Do...........	Terraced, closed end, contour	9.24	9.20	9.12	9.17	12.87	13.02	12.08	12.66	13.26	13.45	12.35	13.02
	Average	9.14	8.92	9.00	9.02	12.76	13.04	11.84	12.54	12.94	13.37	12.29	12.86
Average	With slope	9.16	8.75	8.73	8.88	12.59	12.72	11.40	12.24	12.73	13.14	12.05	12.64
Do...........	Contour	9.35	9.07	8.65	9.03	12.58	12.79	11.51	12.29	12.79	13.25	12.03	12.69
Do...........	Terraced, open end, contour	9.42	9.10	8.88	9.13	12.96	12.98	11.48	12.47	13.05	13.28	12.01	12.78
Do...........	Terraced, closed end, contour	9.47	9.37	9.18	9.33	13.03	13.05	11.97	12.68	13.16	13.34	12.32	12.94

[1] Results for crop year, July 1 to June 30.
[2] Samples taken immediately after harvest, usually last week of June.
[3] Samples taken immediately after seeding, usually latter part of October.
[4] Samples taken about the middle of March.

Table 16. Percent Moisture in Different Foot-Intervals of Soil on Rotation Tillage Areas at Different Times during Cropping Season, 1942-51[1]

Method of tillage	Foot layers	After harvest	After seeding	Beginning spring growth
Stubble Mulched	1	8.67	12.86	13.07
	2	9.04	12.81	13.41
	3	9.30	11.78	12.66
	Average	9.00	12.48	13.05
One-way Plowed	1	8.74	12.56	12.81
	2	8.79	12.62	13.35
	3	9.24	11.49	12.40
	Average	8.92	12.22	12.85
Basin Listed	1	8.82	12.48	13.12
	2	8.82	12.83	13.53
	3	9.28	12.04	12.49
	Average	8.97	12.45	13.05

[1] Landed cultivated on contour.

Table 17. Weeds Produced in Wheat on Areas Tilled by Continuous and Rotation Methods[1]

Year	Pounds per acre						
	Continuous tillage				Rotation tillage		
	Stubble mulched	Plowed	Listed	Basin listed	Stubble mulched	One-way plowed	Basin listed
1943	237	166	131	105	00	00	00
1944	38	16	48	24	21	27	42
1945	216	00	00	00	37	18	00
1946	00	00	00	00	00	00	00
1947	231	00	93	22	22	00	66
1948	811	172	235	307	42	28	7
1949	750	48	70	84	28	44	72
1950	00	00	00	00	00	00	00
1951	00	00	00	00	00	00	00
Average	254	45	64	60	17	13	21

[1] Collected from areas where straw samples were taken.

Table 18. Yield of Wheat Per Acre from Continuous Tillage on Terraced and Unterraced Land at Wheatland Station[1]

Year	Method of tillage	Terraces and direction of cultivation									
		With slope		Contour		Terrace-contour[2]		Terrace-contour[3]		Average	
		Straw tons	Grain bu.	Straw tons	Grain bu.	Straw tons	Grain bu.	Straw tons	Grain bu.	Straw tons	Grain bu.
1942.....	Stubble Mulched	1.49	17.5	1.72	16.4	1.47	15.0	1.49	17.9	1.54	16.7
	Plowed	1.77	14.3	1.58	15.2	1.62	14.3	1.70	14.0	1.67	14.5
	Listed	1.86	18.2	1.68	16.6	1.46	13.4	1.81	15.8	1.70	16.0
	Basin Listed	1.50	14.2	1.87	13.7	1.55	13.9	1.50	13.2	1.61	13.8
	Average	1.66	16.0	1.71	15.5	1.52	14.1	1.62	15.2	1.63	15.2
1943.....	Stubble Mulched	0.66	8.2	0.69	7.6	0.73	6.9	0.63	5.7	0.68	7.1
	Plowed	0.96	9.4	1.01	10.0	0.98	7.7	0.99	7.5	0.99	8.6
	Listed	0.87	9.8	0.87	11.1	0.67	9.5	0.97	10.0	0.85	10.1
	Basin Listed	0.80	9.2	1.09	10.8	0.88	10.7	0.94	10.1	0.93	10.2
	Average	0.82	9.2	0.92	9.9	0.82	8.7	0.88	8.3	0.86	8.8
1944.....	Stubble Mulched	1.20	14.8	1.46	15.8	1.55	16.9	1.36	15.8	1.39	15.7
	Plowed	1.63	20.5	1.86	21.6	1.78	21.1	1.88	20.9	1.79	21.1
	Listed	1.41	18.9	1.65	20.0	1.59	19.3	1.69	21.2	1.59	19.9
	Basin Listed	1.41	16.6	1.72	20.0	1.52	20.1	1.64	20.4	1.57	19.3
	Average	1.41	17.7	1.67	19.2	1.61	19.4	1.64	19.6	1.58	19.1
1945.....	Stubble Mulched	1.36	17.7	1.65	16.0	1.30	18.8	1.44	18.6	1.44	18.0
	Plowed	1.85	26.2	1.94	26.4	1.94	26.3	1.86	24.5	1.90	25.9
	Listed	1.86	24.7	2.06	28.7	1.80	24.9	1.79	26.4	1.88	26.2
	Basin Listed	1.63	23.9	2.02	27.3	2.04	27.2	1.78	26.3	1.87	26.2
	Average	1.67	23.2	1.92	24.6	1.77	24.5	1.72	24.4	1.77	24.2
1946.....	Stubble Mulched	1.11	19.6	0.97	18.5	0.99	18.2	1.33	21.9	1.10	19.6
	Plowed	1.32	25.9	1.31	27.4	1.30	26.9	1.40	25.8	1.33	26.5
	Listed	1.00	19.6	1.13	24.7	1.41	24.0	1.34	23.4	1.22	22.9
	Basin Listed	0.99	19.1	1.37	25.4	1.37	26.1	1.35	26.0	1.27	24.2
	Average	1.11	21.0	1.20	24.0	1.27	23.8	1.35	24.3	1.23	23.3

1947.....	Stubble Mulched	1.11	12.7	1.09	12.6	1.18	13.3	1.13	13.8	1.13	13.1
	Plowed	1.57	22.1	1.68	22.8	1.51	25.0	1.56	21.9	1.58	22.9
	Listed	1.47	20.8	1.53	20.4	1.32	18.6	1.63	20.9	1.49	20.2
	Basin Listed	1.43	19.7	1.68	22.1	1.69	23.3	1.43	20.8	1.56	21.5
	Average	1.39	18.8	1.49	19.5	1.42	20.0	1.44	19.4	1.44	19.4
1948.....	Stubble Mulched	0.86	15.0	0.74	12.3	0.93	15.6	0.97	15.6	0.88	14.6
	Plowed	0.84	14.2	0.89	16.8	0.88	17.4	0.88	17.5	0.87	16.5
	Listed	0.85	15.4	0.89	15.9	0.77	15.9	1.06	18.9	0.89	16.5
	Basin Listed	0.77	13.5	0.93	15.6	1.09	17.2	1.03	18.9	0.95	16.3
	Average	0.83	14.5	0.86	15.1	0.92	16.5	0.98	17.7	0.90	16.0
1949.....	Stubble Mulched	1.07	11.9	1.09	13.2	0.91	11.3	0.91	9.0	1.00	11.3
	Plowed	1.23	10.4	1.06	10.1	1.04	10.4	1.06	8.5	1.10	9.8
	Listed	1.06	11.3	1.18	11.6	1.07	11.0	1.25	11.1	1.14	11.2
	Basin Listed	1.27	9.8	1.26	11.0	1.27	10.2	1.07	9.2	1.22	10.0
	Average	1.16	10.7	1.15	11.5	1.07	10.7	1.07	9.4	1.11	10.6
1950.....	Stubble Mulched	0.84	17.4	0.78	16.5	0.86	18.1	0.94	19.2	0.86	17.8
	Plowed	0.93	19.5	1.18	21.3	1.15	22.5	1.14	23.0	1.10	21.6
	Listed	0.83	17.2	0.93	18.7	1.00	19.2	1.00	21.7	0.94	19.2
	Basin Listed	0.76	15.2	1.01	20.1	1.08	21.3	1.06	22.3	0.98	19.7
	Average	0.84	17.3	0.98	19.2	1.02	20.3	1.04	21.6	0.97	19.6
1951.....	Stubble Mulched	0.80	14.5	0.78	15.0	0.77	14.6	0.72	13.2	0.77	14.3
	Plowed	1.06	20.9	1.06	22.0	1.00	22.5	0.95	18.4	1.02	20.9
	Listed	0.99	17.8	1.06	20.5	1.03	20.1	1.06	17.4	1.03	18.9
	Basin Listed	0.90	18.8	1.06	21.3	1.18	22.2	0.99	17.3	1.03	19.9
	Average	0.94	18.0	0.99	19.7	0.99	19.8	0.93	16.6	0.96	18.5
Average.. 1942-51..	Stubble Mulched	1.05	14.9	1.10	14.4	1.07	14.9	1.09	15.1	1.08	14.8
	Plowed	1.32	18.3	1.36	19.4	1.32	19.4	1.34	18.2	1.33	18.8
	Listed	1.22	17.4	1.30	18.8	1.21	17.6	1.36	18.7	1.27	18.1
	Basin Listed	1.15	16.0	1.40	18.7	1.37	19.2	1.28	18.4	1.30	18.1
	Average	1.18	16.5	1.29	17.8	1.24	17.8	1.27	17.6	1.24	17.4

1 For crop year, July 1 to June 30.
2 One end of terrace open.
3 Closed-end terraces.

Table 19. Yield of Wheat per Acre from Rotation Tillage at Wheatland Station[1]

Year	Stubble mulched		Basin listed		One-way plowed	
	Straw tons	Grain bushels	Straw tons	Grain bushels	Straw tons	Grain bushels
1942	1.21	13.4	1.38	10.9	1.27	12.3
1943	.99	9.6	.90	11.1	.81	11.7
1944	1.47	16.0	1.52	17.6	2.27	21.1
1945	1.62	23.8	2.07	28.3	1.73	27.1
1946	1.60	24.1	1.46	23.4	1.26	23.4
1947	1.15	20.1	1.46	21.5	1.75	21.8
1948	.91	15.6	1.05	19.0	1.01	18.5
1949	1.14	9.0	.99	8.6	1.04	9.9
1950	.96	19.9	.97	20.1	.96	20.2
1951	1.10	22.5	1.30	24.8	1.03	23.1
Average	1.22	17.4	1.31	18.5	1.31	18.9

[1] Land cultivated on contour.

Table 20. Height of Wheat Plants on Continuous Tillage Plots at Wheatland Station[1]

Year	Stubble mulched	Plowed	Listed	Basin listed
1943	24.6	25.6	25.5	25.6
1944	32.0	35.0	34.0	33.0
1945	34.4	37.9	37.9	37.9
1946	30.1	30.2	29.4	30.2
1947	34.4	36.9	37.4	37.6
1948	22.1	22.0	22.7	20.8
1949	32.7	32.0	32.8	33.2
1950	21.9	21.3	21.9	22.4
1951	22.6	23.1	22.6	23.8
Average	28.31	29.33	29.35	29.39

[1] These data were calculated from random measurements taken at 18 locations throughout each plot each year.

Table 21. Percentage of White Heads in Wheat on Wheatland Station[1]

Year	Continuous tillage				Rotation tillage		
	Stubble mulched	Plowed	Listed	Basin listed	Stubble mulched	One-way plowed	Basin listed
1943	3.1	0.5	1.3	0.7	0.1	0.2	0.7
1944	10.6	0.5	1.0	1.2	0.2	0.5	0.2
1945	12.4	2.6	2.0	4.8	1.4	1.8	2.1
1946	5.5	0.1	0.6	0.2	0.9	0.3	1.0
1947	11.8	0.9	3.2	2.8	5.6	5.2	10.5
1948	2.0	0.1	1.0	1.0	0.4	0.2	0.2
1949	0.8	0.0	0.7	0.7	1.3	1.7	0.9
1950	0.8	0.7	0.5	0.8	0.5	0.7	0.0
1951	0.4	0.3	0.4	0.7	0.2	0.0	0.1
Average	5.3	0.6	1.2	1.4	1.2	1.2	1.7

[1] Percent calculated from four random counts of 100 head each per plot. White heads in wheat on this station were identified as being foot-rot by Dr. K. Star Chester, Head, Botany and Plant Pathology Department, Oklahoma A. and M. College.

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